University of Adelaide

IMPERIAL MYCOLOGICAL
23 JAN 1940
INSTITUTE

REPORT

OF THE

WAITE AGRICULTURAL RESEARCH INSTITUTE

SOUTH AUSTRALIA

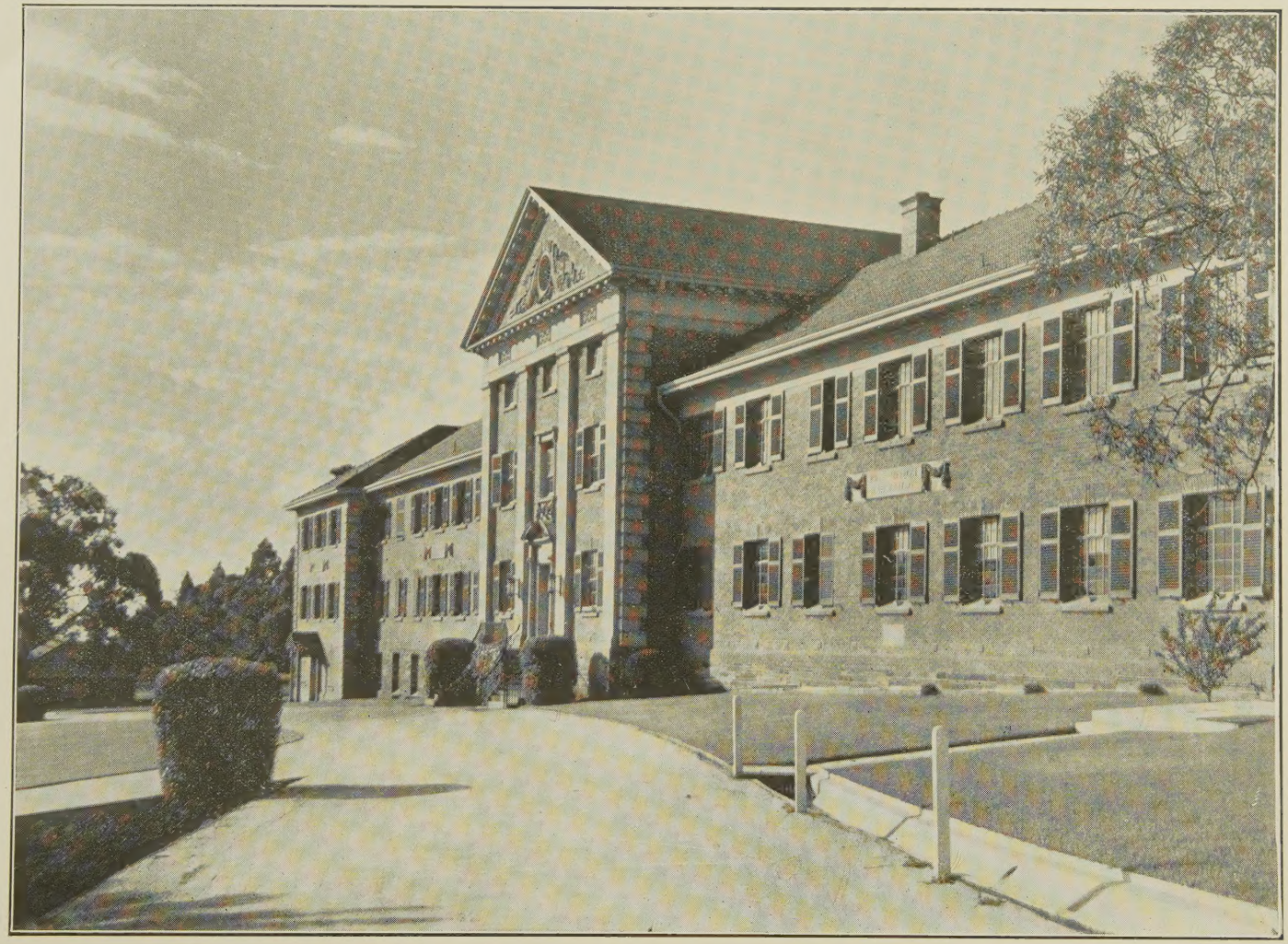
1937-1938

ADELAIDE
AT THE HASSELL PRESS
1939

REPORT OF THE WAITE AGRICULTURAL RESEARCH INSTITUTE

Digitized by the Internet Archive
in 2025

https://archive.org/details/biennial-report-waite-agricultural-research-institute_1937-1938



THE LABORATORIES OF THE WAITE AGRICULTURAL RESEARCH INSTITUTE.

University of Adelaide

REPORT

OF THE

WAITE AGRICULTURAL RESEARCH INSTITUTE

SOUTH AUSTRALIA

1937-1938

ADELAIDE
AT THE HASSELL PRESS
1939

Registered at the General Post Office, Adelaide
for transmission through the post as a book

Wholly set up and printed in Australia
at The Hassell Press, Adelaide

CONTENTS

PAGE

THE COUNCIL OF THE UNIVERSITY vii

THE STAFF ix

THE WAITE AGRICULTURAL RESEARCH INSTITUTE

1. Introduction 1
2. Scientific Work of the Institute 3

THE WORK OF THE INSTITUTE

Agronomy, Agrostology, and Plant Genetics

1. Field Crops 5
2. Pasture Investigations 10
3. Plant Breeding and Genetics 21
4. Investigations Relating to Soil Erosion and Pasture Regeneration 27
5. Sheep-Rugging Investigations 30
6. Botanical Service 31

Plant Physiology 31

Plant Pathology 35

Entomology 40

Soils and Agricultural Chemistry

1. Soil Investigations 48
2. Mineral Deficiencies 51
3. The Chemistry of Pastures 56
4. The Chemistry of Plant Viruses 58

Bacteriology 60

Climatology 62

WAITE ARBORETUM 63

PAPERS PUBLISHED BY THE STAFF OF THE WAITE AGRICULTURAL RESEARCH INSTITUTE, 1937–38 64

METEOROLOGICAL RECORDS 89

THE SOIL PROFILE AT THE WAITE INSTITUTE 94

RECORDS OF FIELD EXPERIMENTAL WORK 97

The University of Adelaide

VISITOR:

His Excellency the Governor

CHANCELLOR:

The Hon. Sir George John Robert Murray, K.C.M.G., B.A., LL.M.

VICE-CHANCELLOR:

Professor Sir William Mitchell, K.C.M.G., M.A., D.Litt.

THE COUNCIL:

C. L. Abbott, B.A., LL.B., M.P.
W. J. Adey, C.M.G.
The Hon. Sir J. Langdon Bonython, K.C.M.G.
R. H. Chapman, M.E.
Professor Sir Robert Chapman, Kt., C.M.G., M.A., B.C.E., M.I.E. (Aust.).
A. M. Cudmore, C.M.G., M.B., B.S., F.R.C.S.
The Hon. C. R. Cudmore, B.A., M.L.C.
Sir William Goodman, Kt., M.I.C.E., M.I.E.E.
The Hon. Sir David Gordon, Kt., M.L.C.
Professor Kerr Grant, M.Sc.
The Hon. E. W. Holden, B.Sc., M.L.C.
F. S. Hone, B.A., M.B., B.S.
W. J. Isbister, M.B.E., K.C., LL.B.
Professor Sir Douglas Mawson, Kt., O.B.E., B.E., D.Sc., F.R.S.
Helen M. Mayo, O.B.E., M.D., B.S.
J. McLeay, M.P.
The Hon. Sir Herbert Angas Parsons, Kt., LL.B.
A. G. Price, C.M.G., D.Litt., F.R.G.S.
W. Ray, M.B., B.S., B.Sc.
T. E. Barr-Smith, B.A.
Professor J. McKellar Stewart, M.A., D.Phil.
A. V. Thompson, M.P.
J. F. Ward, M.A.
R. A. West, M.A.

FINANCE COMMITTEE OF THE COUNCIL AND BOARD OF MANAGEMENT OF THE INSTITUTE:

Sir William Goodman, *Chairman.*

The Chancellor
The Vice-Chancellor
Mr. C. L. Abbott
Hon. Sir Langdon Bonython
Professor Sir Robert Chapman
Hon. Sir David Gordon
Hon. E. W. Holden
Dr. F. S. Hone
Mr. W. J. Isbister
Mr. J. McLeay
Hon. Sir Angas Parsons
Mr. T. E. Barr Smith
Mr. A. V. Thompson

F. W. Eardley, B.A., *Registrar.*

The Waite Agricultural Research Institute

STAFF (at 31st December, 1938):

Director, Waite Professor of Agricultural Chemistry and Chief, Division of Soils: J. A. Prescott, D.Sc.

Soils and Agricultural Chemistry:

Chemical Laboratory.

Chemists: R. J. Best, M.Sc., C. S. Piper, M.Sc., A. E. Scott, M.Sc., *J. S. Hosking, M.Sc., *A. Walkley, B.Sc., B.A., Ph.D.

Assistant Chemist: H. P. C. Gallus, M.Sc.

Analyst: *R. E. Shapter, A.A.C.I.

Spectrographer: *A. C. Oertel, M.Sc.

Technical Assistants: *H. R. Skewes, V. A. Stephen.

Laboratory Assistant: C. H. Williams.

Soil Surveys.

Senior Soil Survey Officer: *J. K. Taylor, B.A., M.Sc.

Soil Surveyors: *T. J. Marshall, M.Ag.Sc., *C. G. Stephens, M.Sc.

Surveyor and Cartographer: *P. D. Hooper.

Assistant Soil Surveyors: *J. G. Baldwin, B.Ag.Sc., *G. D. Hubble, B.Ag.Sc., *R. L. Crocker, B.Sc., *B. E. Butler, B.Ag.Sc., *R. Smith, B.Ag.Sc., *R. I. Herriot, B.Ag.Sc.

Agronomy, Agrostology, and Plant Breeding:

Head of Department and Senior Agronomist: H. C. Trumble, M.Ag.Sc., D.Sc.

Agronomy and Agrostology.

Agrostologist: *C. M. Donald, B.Ag.Sc.

Botanist: G. H. F. Clarke, B.Sc.

Assistant Agrostologist: J. R. Goode, B.Ag.Sc.

Assistant Agronomists: C. A. N. Smith, B.Ag.Sc., D. C. Wark, M.Ag.Sc., K. Woodroffe, B.Ag.Sc.

Curator of Herbarium: Constance M. Eardley, B.Sc.

Technical Assistants: D. L. Parker, E. J. Leaney, Dorothy W. Drew.

Laboratory Assistants, M. Meave Burnett, Marjory M. Laurence, Helen W. Teague, Helen M. Douglas.

Plant Breeding and Genetics.

Geneticist: I. F. Phipps, B.Ag.Sc., M.Sc., Ph.D.

Technical Assistant: S. R. Hockley.

Entomological Laboratory:

Head of Department and Professor of Entomology: J. Davidson, D.Sc.

Entomologists: D. C. Swan, M.Sc., H. G. Andrewartha, M.Ag.Sc.

Technical Assistant: Helen M. Brookes.

Laboratory Assistant: *F. W. Cook.

Plant Pathological Laboratory:

Head of Department: D. B. Adam, B.Ag.Sc.
Plant Pathologist: T. T. Colquhoun, M.Sc.
Assistant Plant Pathologist: Jean McNeil, M.Sc.
Laboratory Assistant: Roma E. Woods.

Plant Physiological Laboratory:

Head of Department: A. H. K. Petrie, Ph.D., D.Sc.
Assistant Plant Physiologist: R. F. Williams, M.Sc.
Assistants in Plant Physiology: Ruth Watson, M.Sc., Joyce E. Brooke, B.Sc.
Voluntary Worker: Joan Walkley, M.Sc.
Laboratory Assistant: Margaret B. Harral.

Bacteriological Laboratory:

Soil Bacteriologist: *T. H. Strong, B.Ag.Sc.
Wine Bacteriologist: F. H. Hooper, B.Ag.Sc.

Statistics:

Statistician: E. A. Cornish, B.Ag.Sc.

Clerical Staff:

Clerical Officer: G. L. Gooden, A.F.I.A.
Library Officer: E. M. Gene Goodale.
Typists: Kathleen Brinkworth, Joan C. Hogben, Jean M. Thomas.

Photographer:

A. D. Cocks.

Hon. Wool Instructor:

A. H. Codrington.

Field Station—Division of Animal Nutrition:

Chemist: *A. W. Peirce, M.Sc.
Technical Assistant: *R. W. Langsford.

Farm:

Manager: K. A. Pike.
Foreman: B. W. Hollins.

Temporary and Voluntary Workers during 1937 and 1938:

G. H. Burvill, G. L. Amos, L. J. Dumbleton.

Members of the Staff who have left for other appointments since January 1, 1937:

Dr. A. E. V. Richardson, Director, to take up the position of Deputy Chief Executive Officer to the Council for Scientific and Industrial Research, Melbourne.

Dr. J. G. Davies, Agrostologist, to take up appointment as Senior Agrostologist, Division of Plant Industry (C.S.I.R.), Canberra.

*Miss Jessie L. Thomas.

Mr. R. H. Jones.

* Officers of the Commonwealth Council for Scientific and Industrial Research.

The Waite Agricultural Research Institute

1. Introduction.

The Waite Agricultural Research Institute was established in 1924 as a result of the gift of the late Mr. Peter Waite to the University of Adelaide for the purpose of furthering the cause of education and research in agriculture and allied subjects. The original endowment comprises an estate of 299 acres of agricultural and grazing land situated near Glen Osmond, a mansion house, and a Trust Fund of £58,450.

The estate lies on the scarp of the Adelaide foothills, within four miles of the city of Adelaide. Portion of the estate comprises wheat land, 280–390 feet above sea-level, whilst the remainder is representative of the hilly country at the foothills of the Mount Lofty Ranges. To the original estate have been added 82 acres by purchase, and a further area of 115 acres associated with the Urrbrae Agricultural High School is leased from the Education Department of South Australia.

The Council of the University decided that the best means of giving effect to the wishes of the donor would be the establishment of an Agricultural Research Institute, in order to enlarge the stock of knowledge relating to agriculture in the widest sense, for the benefit of those engaged in production, as farmers or pastoralists. It appointed its Finance Committee to act as the Board of Management of the Institute.

The active work of the Institute began in March, 1925, and laboratories were improvised in the existing buildings on the estate, pending the erection of permanent structures. The permanent laboratories have been made possible through the generosity of the late Sir John Melrose and the families of the late Mr. John Darling and Mr. Frederick Ranson Mortlock. The John Melrose Laboratory was opened in 1929, and the John Darling Laboratory in 1930. The Ranson Mortlock Laboratory was erected under the terms of the Ranson Mortlock Trust. The foundation-stone was laid by Mrs. Rosye F. Mortlock, in May, 1937, and the completed building formally declared open by His Excellency the Governor of South Australia, Sir Winston Dugan, in April, 1938.

The design of the buildings is such as to permit of additional laboratories as circumstances demand.

In addition to the laboratories, a range of glasshouses, two implement sheds, and a cereal barn have been erected since 1925. The glasshouses include two designed for general work in agronomy, plant pathology, and physiology, one designed for entomology, and a completely enclosed house with numerous compartments suitable for investigations demanding freedom from outside contamination, whether in the form of dust, insect pests, or bacterial infection.

This latter glasshouse has been constructed and is maintained by the Council for Scientific and Industrial Research, primarily for investigations in plant viruses and soil bacteriology.

In 1927 the Empire Marketing Board, the Council for Scientific and Industrial Research, and the University of Adelaide jointly agreed to provide funds for the investigation of the mineral content of pastures in Australia. The Empire Marketing Board agreed to contribute a sum of £1,875 per annum for a period of five years for this co-operative investigation. The Council for Scientific and Industrial Research has contributed annually a sum of £937 towards the maintenance costs of the investigation. When the Empire Marketing Board was discontinued the Trustees of the Carnegie Institution of New York provided funds over a two-year period for the maintenance of these pasture investigations, provided that the University undertook to continue the investigations subsequent to the expiry of the grant. The investigations have been continued jointly by the University and by the Council for Scientific and Industrial Research.

Since 1927 a field station equipped with feeding pens and metabolimeter rooms has been maintained at the Waite Institute by the Division of Animal Health and Nutrition of the Council for Scientific and Industrial Research. A breeding flock of Merino ewes is also maintained at the Institute by the Division.

Since 1929 the Waite Institute has been the headquarters of the Division of Soils of the Council for Scientific and Industrial Research.

Under the will of Mrs. Elizabeth Macmeikan, widow, and daughter of the late Mr. Peter Waite, who died on April 5, 1931, her residuary estate, after payment of certain bequests, was left in trust to the University of Adelaide. The net income in the residuary estate is to be paid to the University in perpetuity for establishing and maintaining the study of agriculture, botany, zoology, veterinary science, entomology, horticulture, and forestry by the University, either in connection with the Waite Agricultural Research Institute or otherwise.

In August, 1936, the family of the late Mr. Frederick Ranson Mortlock offered the Council of the University the sum of £25,000 for research work in connection with soil erosion and regeneration of pastures on pastoral lands. The conditions attaching to the gift, which was contributed equally by Mrs. Rosye F. Mortlock (the late Mr. Ranson Mortlock's mother) and his brother, Mr. John T. Mortlock, included the following:

1. The gift to be known as the "Ranson Mortlock Trust" for "Research work in connection with soil erosion and regeneration of pastures on pastoral lands."
2. A suitable building to be erected at the Waite Institute for the purpose of the Trust, such a building to cost not less than £10,000, and to be named the Ranson Mortlock Building.

The conditions were accepted by the University; the laboratory has been com-

pleted, and investigations on pasture regeneration under the terms of the Trust have been initiated.

Since 1937 Mr. James Waite, son of the late Mr. Peter Waite, has made an annual contribution of £100 for research work in connection with the problem of soil erosion.

During 1938 Mr. Harry Showell presented a Watson microscope of high precision to the Institute.

Apart from its original and subsequent endowments the Waite Research Institute derives its income from appropriations under Acts of Parliament of South Australia, from Commonwealth sources through the Council for Scientific and Industrial Research, and for specific investigations from such organizations as Imperial Chemical Industries Limited, the Australian Wool Board, and the Australian Wine Board.

From the beginning of 1925 until early in 1938 the Waite Institute was under the direction of Dr. A. E. V. Richardson. To Dr. Richardson and to Sir Walter Young (who was Chairman of the Finance Committee from 1927 to 1935) the Waite Institute is deeply indebted for the solid progress made during the early years of its establishment.

2. Scientific Work of the Institute.

The main objective of the Institute is to enlarge the stock of knowledge relating to agriculture in the widest sense, and to pass it on to those actively engaged in agricultural and pastoral pursuits. Expressed in more precise terms, the aim is to conduct researches on plant and soil problems relating to agriculture, and on the insect and fungus pests which affect production.

Under the terms of the University of Adelaide Act 1935, and a subsequent Amendment Act of 1937, the Waite Institute, in addition to conducting researches into specified branches of agricultural science, is to provide advisory services in botany, plant pathology, and entomology to the Minister of Agriculture. By agreement these services have recently been extended to the Minister of Afforestation.

The University of Adelaide maintains a School of Agricultural Science and courses of instruction for the degree of B.Ag.Sc. Courses of instruction in agriculture, agricultural chemistry, mycology, plant pathology, and entomology for this degree are provided at the Waite Institute.

Although extension work in agriculture is not a function of the Institute, educational work is effected through visits of Agricultural Bureaux, parties of farmers, and other visitors to the experimental fields and laboratories. During the period under review, the Waite Institute has co-operated with the Australian Broadcasting Commission in providing a weekly talk from Stations 5CL and 5CK during the Countryman's Session.

The scientific work of the Institute is centred round the study of the principles of crop and pasture husbandry and of the problems which may be asso-

ciated with this aspect of agriculture. Animal husbandry is not a feature of the research work of the Institute except in so far as it is necessary for the study of pastures. The main subjects of investigation may be included in the following groups:

Agronomy, Agrostology, and Plant Genetics.

The investigation of the factors affecting the production of farm crops; the improvement, establishment, and management of pastures; the improvement of cereals and fodder plants by hybridization and selection; the identification and control of weeds.

Plant Physiology.

The investigations of the metabolism and growth of plants of agricultural importance.

Plant Pathology.

Investigations of the diseases of agricultural and horticultural crops and of forest trees.

Entomology.

Investigations of the insect pests of agricultural and horticultural crops and of forest trees.

Agricultural Chemistry and Soil Investigations.

The survey and classification of Australian soils; the investigation of soil fertility problems; the chemical study of plant viruses; the chemical study of pastures.

Bacteriology.

The study of the nodule-forming organism of leguminous plants, with special reference to the use of strains and methods suited to Australian crops and farming practice; the investigation of secondary fermentations in wines.

The Work of the Institute

Agronomy, Agrostology, and Plant Genetics

South Australia may be divided into three main regions: (1) the higher rainfall areas, where intensive agriculture may be practised; (2) the wheat belt; and (3) the semi-arid and arid pastoral country.

The first region, which receives a rainfall of approximately 25 inches and over, and to which should be added the irrigation areas, is devoted to a more intensive agriculture; it contains undeveloped or partly developed country in which there are great possibilities for improved production. Investigational work relating to the problems of this region is concerned chiefly with the development and management of sown permanent pastures, and to the establishment of pastures on difficult soil types.

In the wheat belt, which comprises most of the agricultural areas, the rainfall varies from 10 to over 20 inches, with a definite winter incidence suitable for the production of cereal crops. The agricultural problems under investigation in this area are concerned with the development of a system of cereal culture and grassland management which will make the best use of the seasonal rainfall. Investigations are directed mainly to a study of the principles underlying the maintenance of soil fertility, the rotation of crops, tillage of the soil, manuring of crops and grassland, the establishment and maintenance of pastures in relation to the grazing animal, and the production of improved varieties and strains of farm crops and pasture plants.

The arid and semi-arid region, occupying approximately 81 per cent. of the State, has a rainfall of less than 10 inches, and is devoted exclusively to pastoral pursuits—the grazing of sheep and cattle on the native grasses and shrub flora. The plant problems in this area are related to regeneration and maintenance of the natural perennial flora and to the prevention of erosion. An investigation of these problems has recently been commenced in the north of the State.

1. FIELD CROPS.

(1) *Permanent Rotation Experiments.*

Experimental work on rotations is, of necessity, of long duration and semi-permanent in nature. Trends in fertility under different systems of rotation are measurable only after several rotational cycles have been passed through.

A series of 11 rotational systems was laid down in 1925 to determine the effect of each system on the yield of wheat as the main crop in the Adelaide Plains

environment. Each course of the 11 rotations is represented every year so that the effect of seasonal variability is reduced to a minimum.

The average yields of each crop in each rotation for the period 1926–38 are presented in Table 1, on page 99, where it will be seen that the rotations giving high yields of wheat, and therefore those in which fertility is being maintained, are: (1) wheat, oats, pasture, fallow (44·82 bush. per acre); (2) wheat, peas, fallow (39·69 bush. per acre); (3) wheat, barley, fallow (39·19 bush. per acre); (4) wheat, pasture, fallow (39·00 bush. per acre). On the other hand, the wheat, fallow, wheat, fallow rotation gave a mean yield of 36·52 bushels per acre, and wheat continuously 16·46 bushels per acre.

Rotations which involve continuous cropping, such as wheat, peas; wheat, barley, peas; and wheat continuously are now heavily infested with weeds.

This rotation experiment will be continued, and might be expected to give results of increasing value in the course of time. Other investigations, suggested by the above results, are concerned with the use of wider rotations including peas and grazed temporary pasture, the application of nitrogenous fertilizers to stubble-sown cereals, and the use of forage crops other than pastures, and are discussed in other sections of this Report.

(2) *Fertilizer Experiments: The Effect of Nitrogenous Fertilizers on Cereals.*

A full account of the work conducted on the effect of nitrogenous fertilizers on stubble-sown crops was published in the Waite Institute Report 1933–36. The experiments were continued in 1937, and extended to country centres.

The average annual responses obtained from the application of sulphate of ammonia to barley and oats sown on stubble are given in detail in Tables 2 and 3 on pages 100 and 101. The average yields for the five-year period 1933–37 are as follows:

Sulphate of Ammonia (cwt. per acre).	Barley (bush. per acre).		Oats (bush. per acre).	
	Yield.	Increase.	Yield.	Increase.
0	27·26	—	32·75	—
½	34·48	7·22	40·37	7·62
1	42·93	15·67	49·46	16·71
2	54·91	27·65	64·91	32·16
3	59·68	32·42	72·28	39·53

Increases in total produce due to the application of nitrogenous fertilizers to barley and oats correspond approximately to the increase in yield of grain shown above.

The average moisture and nitrate nitrogen determinations to a depth of three feet under fallow and stubble crops during the years of this trial are as follows:

Soil Moisture (per cent.). Mean Over the Depth 0–3 Feet.

	April.	Seeding (June).	Maximum Tillering (September).	Harvest (November).
Soil under fallow crop	17·3	21·5	19·8	15·9
Soil under stubble crop	14·4	19·7	20·0	17·7

Nitrate Nitrogen (Parts per Million). Mean Over the Depth 0–3 Feet.

	April.	Seeding (June).	Maximum Tillering (September).	Harvest (November).
Soil under fallow crop	9·2	8·9	2·2	1·4
Soil under stubble crop	3·6	3·4	1·3	1·6

At seeding the amount of nitrate nitrogen found in the surface layers of the fallow was sufficient to meet the requirements of a substantial wheat crop. In stubble land the available nitrogen had been largely used by the previous crop, and conditions generally during the dry summer do not favour nitrification. The amount of nitrate present at seeding was insufficient to meet the requirements of a heavy cereal crop.

The fallow soil normally contained more moisture at seeding than the stubble-ploughed soil, but the difference between the moisture content of the two was not great, and was unimportant compared with the difference in nitrate content.

Census studies showed that the chief effect of sulphate of ammonia was to increase the tillering of the plants on stubble-ploughed soils. In the case of barley, there was a large increase in the number of ears at harvest, but only a small increase in the size of the ears. In the case of oats, the chief effect was a marked increase in the number of grains to each panicle.

Trials on private farms at a score of centres in the country districts of South Australia were conducted in conjunction with the Department of Agriculture. The chief factors associated with large responses to sulphate of ammonia were a low nitrate content of the soil at seeding, an adequate rainfall during the growing period of the crop, and absence of weed competition in the early stages of growth.

In trials in the mid-north of the State, and on Yorke Peninsula, where the soil nitrate was generally high at seeding, stubble-sown barley and oats did not give profitable responses to sulphate of ammonia. Profitable responses were obtained from a number of trials in the better rainfall districts, including southern Eyre's Peninsula, Kangaroo Island, and the Central, Southern, and South-Eastern districts of the State.

(3) *Combined Rotational and Fertilizer Experiments.*

A rotation experiment designed to determine the effect of superphosphate, sulphate of ammonia, and lime on wheat, oats, barley, and peas in four-course rotations was commenced in 1936. The rotations are as follows:

A	*B*	*C*	*D*
Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat
Peas	Oats	Barley	Wheat
Pasture	Pasture	Pasture	Pasture

Rotations A and B were commenced in 1936, and rotations C and D in 1937.

Each course of the rotation is represented by a section of 27 plots (all combinations of three levels of each fertilizer, superphosphate, sulphate of ammonia and lime) every year; there are therefore 16 sections and a total of 432 plots in the experiment. Fertilizers are applied to the cereals, but not to the pasture. The cereals are harvested for total produce and grain, while the pasture plots are sampled for yield prior to being grazed with sheep. Residual effects of the previous fertilizer treatments will be manifest in the yield of pasture.

The results for the years 1936–38 are presented in Table 5 on page 103. The results, however, cannot be fully evaluated until at least one complete cycle of four years has been passed through.

In rotations A and B the residual effect of superphosphate applied to the cereal crops in 1936–37 has increased considerably the yield of pasture grown in 1938. In rotation A the yield of pasture following a pea crop is much greater than after a wheat crop in rotation C.

(4) *Investigations on the Effect of Forage Crops and Temporary Pasture on the Yield of Wheat in Four-Course Rotations.*

The influence of forage crops on the maintenance of soil fertility is being investigated in a series of five four-course rotations. These crops, which are followed in each case by grazed temporary pasture, are subjected to differential treatments of feeding-off and harvesting. Fertility trends under rotation crops, and in comparison with the wheat-fallow rotation, are measured by the yield of wheat sown on fallow. The rotations are as follows:

A	*B*	*C*	*D*	*E*
Fallow	Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat	Wheat
Peas	Clover	Barley	Oats	Fallow
Pasture	Pasture	Pasture	Pasture	Wheat

A basal dressing of 2 cwt. per acre of superphosphate is applied to all crops except the pasture. In the third year of rotations A–D one-half of the area under the forage crops is grazed and the other half cut for yield of total produce, and in the case of oats, barley, and peas, for grain yield.

Yield results for the two years that the experiment has been running are presented in Table 4 on page 102, where it will be seen that the yield of temporary pasture is in all cases greater after grazing of the previous forage crop than after cutting for hay. Furthermore, the highest yield of pasture has been obtained from rotation A, in which grazed peas preceded the pasture. However, the experiment must run for at least one complete cycle before definite conclusions can be drawn.

(5) *Flax Investigations.*

Investigations were commenced in 1937 to test the possibility of growing fibre flax in South Australia, and of producing high-grade seed of the variety Liral Crown. (For detailed results see Tables 7 and 8 on pages 108 and 109.)

In 1937 the treatments employed involved early and late sowing (21st May and 22nd June), seed rates of 40, 60, 80, and 100 pounds per acre, and the application of 2 cwt. superphosphate with and without 2 cwt. sulphate of ammonia. The Liral Crown seed used was imported from England.

The crop grew vigorously, and produced high yields of total produce; mean yield of all early-sown plots was 55·32 cwt. per acre. Heavy rains just prior to harvest reduced the yield of seed and damaged the sample. The mean yield of seed for all early-sown plots was 11·38 bushels per acre. The yield of total produce was increased by early sowing, higher seed rates, and the application of sulphate of ammonia. Seed yields were increased by early sowing, while the higher seed rates and the application of sulphate of ammonia lowered seed production. Samples of flax straw from the different treatments were forwarded to the Division of Forest Products, Council for Scientific and Industrial Research, Melbourne, for retting and scutching. The report received indicated that all the samples were of excellent quality, particularly with regard to length, colour, uniformity, and tensile strength, and compared more than favourably with anything so far produced elsewhere. Neither treatments nor differences in yield affected the quality of the fibre.

In 1938 the treatments employed were early and late sowing on fallow at seed rates of 20, 40, 60, and 80 pounds per acre, with two levels of superphosphate, 1 cwt. and 2 cwt. per acre.

The flax grew well, and, despite a very dry spring, the yields were satisfactory and the seed sample comparable in quality and viability with the original imported seed. Early sowing, heavier seed rates, and the higher phosphate dressing all significantly increased the yield of total produce; mean yield of all early-sown plots was 45 cwt. per acre. Yields of seed were increased by early sowing, but were unaffected by seed rate or the higher phosphate dressing; mean yield of all early-sown plots was 8·79 bushels per acre.

The report from the Division of Forest Products on samples from the 1938 harvest confirmed the results of retting and scutching of the 1937 harvest. The mean yield of fibre from the flax straw was 14·1 per cent.

Thus, over a period of two relatively unfavourable seasons, flax of high fibre quality has been grown successfully under the conditions existing at the Waite Institute; furthermore, both seed and straw yields compare favourably with those obtained elsewhere. These investigations are being continued.

(6) *Fertilizer and Time and Rate of Sowing Tests with Canary Grass.*

Canary Grass (*Phalaris canariensis*) is not likely to become a very important crop in this State because of the limited demand for the seed. It will, however, provide a cash crop for a limited number of farmers, provided that the production of good quality seed is controlled to meet requirements.

In tests carried out at the Waite Institute in 1935 significantly greater re-

sponses to higher dressings of superphosphate were obtained as the seed rate increased. The highest yield obtained was with 24 lb. seed and 2 cwt. superphosphate per acre. The results of the 1936 investigations are recorded in another section of this Report (Table 6, page 107).

In 1936, early sowing, when compared with late sowing, gave more than double the yield of both total produce and seed, whereas varying the seed rate and applying 1 cwt. sulphate of ammonia per acre in addition to superphosphate did not give any significant differences in yield. Maximum yield of seed (14·7 cwt. per acre) was produced by early seeding. Varying the seed rate from 16 to 24 lb. per acre did not affect the yield.

In 1937 duplicate plots of one-eighth acre were sown early and late with 16 lb. seed and 2 cwt. superphosphate per acre on fallow. Heavy yields of total produce were obtained, 77·68 and 62 cwt. per acre respectively. Owing to lodging and the ravages of birds the seed yields were light, being 7·62 and 6·95 cwt. per acre respectively.

2. PASTURE INVESTIGATIONS.

(1) *General.*

New developments in pasture investigation have been associated with the management of sown pastures in the higher rainfall areas of the State, and an extension into the low rainfall country. This comprises the Mallee, with an influential winter rainfall as low as 5½ inches, and the semi-desert shrub steppe of the north-west pastoral area, where the rainfall is sporadic and the soil liable to drift on removal of the native vegetation through continuous grazing and drought. Similarly, in the semi-arid agricultural areas, the clearing of the Mallee and the subsequent tillage operations have produced areas of drifty sand which require the use of sand-binding cover crops such as rye-corn, before pasture plants can be effectively established.

In addition to these new projects research has been continued on such problems as the response of pasture to fertilizer treatment, the testing of pasture species and strains, the improvement of pasture plants by selection and breeding, the question of associated growth between legumes and non-legumes, and the development of pasture experimental technique. Statistical research is in progress on the size of plots, number of replications, and size of samples in pasture investigations.

(2) *Top-dressing of Natural Pastures.*

Investigations which dealt entirely with natural pastures formed an important phase of the initial work on the mineral content of pastures. The first experiment, designed in 1925 to determine the effect of equivalent dressings of phosphorus (40 lb. P_2O_5 per acre) in the form of superphosphate, basic slag, rock phosphate, and the effect of nitrate of soda (78 lb. per acre) added to the superphosphate, has been continued as a permanent investigation. The effects of each fertilizer on the

yield of herbage and stock carrying capacity over fourteen years are summarized in Table 9, on page 110.

At the conclusion of ten seasons the relationship between the annual yield of the pasture and the monthly, bi-monthly, and tri-monthly rainfall throughout the season was determined by a regression analysis. It was found that the total yield of natural pastures for the season was largely predetermined by the amount of autumn and early winter rainfall.

Investigations were also conducted at the Waite Institute and at the Experimental Farm, Kybybolite, with a view to ascertaining the effect of phosphatic fertilizers on the carrying capacity, nutritive value, and the mineral content of typical natural pastures. In these tests Merino wethers were maintained continuously on the unmanured and top-dressed pastures over a period of seasons. It was found at each centre that the carrying capacity of the pasture was materially increased by the application of superphosphate, but the live-weight per sheep and the quantity and quality of the wool produced by each sheep were not significantly altered.

Marked changes in chemical and botanical composition were observed as a result of top-dressing. At the commencement of the first year a notable introduction of annual grasses and legumes was taking place. This invasion readily displaced the dominant perennial species (mainly *Danthonia* spp.), more especially on the superphosphate + nitrate of soda plot. The control plot, after fourteen years of similar treatment in respect to grazing, shows very little alteration to its initial botanical composition. A rather interesting occurrence is the ingress of *Trifolium subterraneum* on the rock phosphate plot. The incidence of this legume is well defined by the area dressed with rock phosphate.

Disabilities were evident, however, in the relatively unstable, annual type of pasture produced by top-dressing, and the investigations indicated that the establishment of seeded pastures, based on the utilization of superior pasture species and strains, was necessary for further improvement.

(3) *Tests with Cultivated Pasture Plants.*

As the prevailing climatic conditions of the South Australian agricultural areas more closely resemble those of the countries bordering the Mediterranean, the herbage species commonly used for grassland improvement in temperate regions are of minor value. For pasture development in these areas, therefore, it is necessary to depend on herbage species adapted to a limited growing season (approximately seven months at the Waite Institute). These have been largely selected and developed from naturalized pasture plants, and from those introduced from winter rainfall regions overseas.

A grass garden, established in 1925, has been maintained, and in it grown the recognized herbage species of temperate and subtropical regions, the more valuable native and naturalized pasture plants, and the most promising introduced species. Of the species suitable for sand-drift conditions in semi-arid areas, *Elymus gigan-*

teus (Giant Lyme grass) and *Ehrharta villosa* (South African pyp grass) are at present under test. *Phalaris tuberosa*, Wimmera rye-grass, lucerne, and early-flowering subterranean clover are still the recognized herbage plants of outstanding value under cultivated conditions at the Waite Institute. The garden is designed in order that species of the same genus and strains of the same species are grouped to facilitate comparative observations.

In addition to herbage species, plants suitable for lawns and playing-greens in Southern Australia are grown. Two of the most important groups of creeping grasses for turf production are the couch grasses (*Cynodon* spp.) and the bent grasses (*Agrostis* spp.). In the latitude of Adelaide couch thrives better than bent, and consequently attention is being paid to local strains of fine-leafed couch grass in comparison with commercial and introduced strains. The fine-leafed Transvaal couch (*Cynodon transvaalensis*) is also under test in the turf mixtures.

(4) *Investigations on Pasture Establishment.*

(*a*) *Waite Institute.*

Lucerne has proved a valuable pasture species at the Waite Institute, but under non-irrigated conditions and when subjected to grazing treatment the stand thins out and becomes invaded by annual grasses and other inferior species.

An attempt was therefore made to incorporate Wimmera rye-grass and *Phalaris tuberosa*, alone and in combination, within an already established lucerne stand by surface harrowing. The establishment of the Wimmera rye-grass was successful, and it continued to contribute a satisfactory proportion of the total herbage during the following two years, with up to a maximum of 48 per cent. in the spring cut. On the other hand, although a certain measure of establishment of *Phalaris* resulted from the initial seeding, the competition from the extensive root system of the established lucerne during the following two summers brought about complete disappearance of the species. Significantly increased yields of herbage did not result from the introduction of the Wimmera rye-grass, as the growth of the latter was found to take place largely at the expense of the lucerne.

A sward trial designed to test the establishment and productivity of various grass-legume combinations in two, three, and four species mixtures when sown in autumn and late winter, was laid down at the Waite Institute in 1935. All plots were subjected to grazing, and sample areas were cut for estimation of productivity prior to the sheep being admitted.

The inferiority of the late winter sowing as compared with that of the autumn was manifest not only in the lower initial establishment of all four species (Wimmera rye-grass, *Phalaris tuberosa*, lucerne, and early subterranean clover), but particularly in the greatly reduced numbers of Wimmera rye-grass and early subterranean clover plants in the following year. The perennial species, *Phalaris* and lucerne, were successfully established at both times of seeding, but the individual

plants in each case were much less vigorous in the late winter-sown section. This was borne out in the fourth year of the pasture, when in a comparative cut the autumn-sown section yielded almost double that of the late winter section. In contrast to the lucerne plants, which survived both the first and second summer periods to the extent of 80 per cent. of the plant numbers of the previous year, *Phalaris* plants suffered a severe mortality through the first summer, although a high proportion of the plants still living in the second year lived through the next summer period.

The sown grasses, Wimmera rye-grass and *Phalaris,* when sown either alone or together, contributed more than two-thirds of the seasonal yield in all mixtures during the first two seasons. The yields from the Wimmera rye-grass plots were greater than those from the *Phalaris,* and the addition of the latter species to the Wimmera rye-grass was not reflected in an additional yield.

On account of its summer and autumn growth lucerne proved to be the outstanding legume, particularly in the third year, when it contributed substantially to the yield at each cut made during the season.

(*b*) *Podsolized Soils.*

Podsolized soils occur over extensive areas of the South-East of the State and the Mount Lofty Ranges. Investigational work at Meadows has shown that subterranean clover must be regarded as the basis of permanent pasture development and soil improvement. The development of mixed pasture on these areas may be attained rapidly as a result of the liberal application of superphosphate. The results of this work have shown that the dressings of superphosphate at present employed in the development of subterranean clover pastures can be considerably increased before maximum economic returns are likely to be realized. It is suggested that a dressing of at least 2 cwt. of superphosphate per acre be applied annually for the first three years.

The inclusion of either *Phalaris tuberosa* or Wimmera rye-grass with subterranean clover is necessary for maximum production and to prevent the entry of inferior annual species resulting from the rise in fertility level of the soil.

(*c*) *Heath Soils.*

Investigations over a period of five years have been conducted at Tintinara to determine the most suitable pasture species and the best method of their establishment for the development of permanent pastures on deep sandy soils of the "heath" type, in the Upper South-East of South Australia.

The earliest work had shown that lucerne, *Phalaris tuberosa,* and early-flowering subterranean clover developed a productive pasture in association, but further investigation into methods of establishment revealed that lucerne, early-flowering (Dwalganup) subterranean clover, and Wimmera rye-grass were the outstanding species for the basis of permanent pasture in this area, with lucerne predominant.

The pasture species were sown down under four different conditions, viz. with a cover crop of oats, barley, and peas, and with no cover crop. The cereal cover crops in the seeding year were found to depress the establishment of the associated grasses (Wimmera rye-grass and *Phalaris*), but to have no effect on that of the legumes (subterranean clover and lucerne), whereas the peas cover crop did not affect the establishment of the grasses, but slightly lowered that of the legumes.

While the presence of oats, barley, or peas markedly reduced the yield of pasture in the seeding year, the subsequent development of the pasture sown with oats or barley proved superior to that sown without a cover crop or with peas, whether the cereal had been cut as green forage, as hay, or left for grain.

Phalaris proved very susceptible to the competitive effect of the cover crop, or where that was absent, to Wimmera rye-grass, and could only be successfully established with lucerne or other species offering only limited competition in the early stages.

Annual dressings of superphosphate at the rate of 1½ cwt. per acre proved more productive and profitable than ¾ cwt. per acre. Application of sulphate of ammonia did not influence the productivity of the pasture sown either with or without a cover crop, although profitable increases in the yield of the cereal cover crops resulted from its application.

(*d*) *Heavy Black Soils.*

Extensive areas of heavy black soils located in the South-East of the State form a region of great potential production. Subterranean clover fails to survive beyond the late seedling stage on this soil type, but other legumes such as lucerne, black medic, and strawberry clover are proving of value. The latter has been established from seedings as light as ¼ lb. per acre. Of the grasses, Wimmera rye-grass, *Phalaris tuberosa,* and, in the zones of less severe summers, perennial rye-grass, are the most valuable. In the areas of heavy winter inundation various species and inter-specific hybrids of *Phalaris* are being investigated.

The results of top-dressing the natural pasture of these soils with superphosphate is to produce in the early years a wealth of annual clovers, particularly *Trifolium resupinatum,* but this development is rapidly followed by an influx of inferior annual grasses. Thereafter the seeding of any species which is susceptible to competition in the seedling stage becomes difficult, even with careful preparation of the seedbed. It follows that the succession after top-dressing should not be allowed to proceed too far before the introduction of such species as strawberry clover, lucerne, or *Phalaris* is attempted.

(*e*) *Ironstone Soils of the Mount Lofty Ranges.*

Investigations were commenced in 1936 to determine the reason for the failure of attempts to establish subterranean clover and other pasture species on gravelly (ironstone), sandy soils occurring in parts of the Mount Lofty Ranges. The chief

difficulty has been in the non-responsiveness of these soils to applications of superphosphate when the herbage gave evidence of phosphate deficiency.

In a pot culture experiment, conducted in 1937 with this soil, the yield of subterranean clover was doubled, and the colour and general vigour of the plants much improved by the application of lime over a basal dressing of superphosphate.

In 1938 a field trial was commenced to investigate the effect on a sown pasture consisting of subterranean clover, lucerne, black medic, and cluster clover (*Trifolium glomeratum*) of varying methods of soil preparation, of varying levels of superphosphate and of lime, and of drilling versus broadcasting the superphosphate. Early results suggest that lime will play a major rôle in pasture development on this soil type, possibly through its effect on phosphate availability.

(5) *Response of Seeded Pastures to Fertilizers.*

(*a*) *The Application of Superphosphate and Effect of Surface Cultivation on a Seeded Pasture Mixture at the Waite Institute.*

The rate of seeded pasture fertilization with superphosphate in South Australia is largely determined by economic considerations, but little is known of the highest economic level at which superphosphate can be applied. In view of this, a supplementary experiment to the pasture management trial described later was set out on an extended area of the same pasture mixture, to discover the effect of increments of superphosphate and surface cultivation in the autumn on the yield and botanical composition of the seeded pasture under six-weekly grazing by Merino sheep.

In 1937 the total seasonal yield was 24·9 cwt. of dry matter per acre on the plots receiving no manure, and 27·7 cwt. per acre on the plots receiving 1 cwt. of superphosphate per acre. In 1938 the yields were 30·2 cwt. and 41·4 cwt. per acre respectively, which, allowing for a seasonal increase of 13·7 cwt. on the manured plots, shows a progressive deterioration of the sown pasture when not dressed with superphosphate. Detailed results are given in Table 11 on page 113. The added increment of superphosphate in 1937 increased growth by a mean of approximately 2·6 cwt. of herbage, but in the following year the 2 cwt. and 3 cwt. per acre applications were insignificantly greater than the 1 cwt., indicating the accumulative effects of phosphate in the soil.

Surface cultivation in the autumn of 1937 had no effect on the mixed herbage produced in that year, but in the following year stimulated production slightly. It is evident from this experiment in conjunction with the pasture management trial, that the application of superphosphate at different levels and surface cultivation in autumn before growth commences, are quite subsidiary to the influence of grazing management on pasture production. In fact, the technique of grazing will always be reflected in the yield and botanical composition of any given pasture.

(*b*) *The Application of Nitrogen to a Seeded Pasture Mixture under Hay and Grazing Treatment at the Waite Institute.*

The first permanent pasture mixture to be established at the Waite Institute was seeded in 1930 to a mixture of Wimmera rye-grass, certified New Zealand perennial rye-grass, *Phalaris tuberosa,* and early-flowering subterranean clover.

A basal dressing of 2 cwt. superphosphate per acre has been applied for nine seasons, while one-half (eight) of the plots have received in addition 2 cwt. sulphate of ammonia per annum. The detailed results appear in Table 10, on page 112.

This pasture had become by 1936 *Phalaris* dominant with smaller quantities of clover, except under continuous cutting, which resulted in clover dominance. It was found that the pasture responded to nitrogen slightly in the first year, and actively in the second season. Thereafter, however, the yields have been depressed by nitrogen; this effect was closely associated with the aggressiveness of perennial rye-grass, which responded to the sulphate of ammonia in the second season, and the resulting depression of the more permanent elements, *Phalaris* and subterranean clover. This aggressiveness was only of short duration, however, probably due to a natural selection by the plant itself, the short-lived types dying out after the pasture had been established for three or four seasons. However, it is striking to note the manner in which the perennial rye-grass is rehabilitating itself, probably by a type more suited to the soil and climatic conditions. In the continuously cut section perennial rye-grass has increased from 4·1 per cent. in 1936 to 28·0 per cent. in 1938 on the plots receiving superphosphate alone, and similarly from 4·4 per cent. to 45·1 per cent. of the total yield in the plots receiving sulphate of ammonia in addition to superphosphate. The addition of sulphate of ammonia reduced, in all cases, the incidence of clover, and on the grazed plots increased fertility due to animal fertilization has depressed the clover. On the plots cut for hay *Phalaris* has attained almost complete dominance.

Associated with the above investigations were swards of pure grasses which responded actively to similar dressings of sulphate of ammonia throughout an experimental period of five seasons.

(*c*) *The Effect of Phosphorus and Nitrogen, Alone and in Combination, on the Yield and Botanical Composition of Two Different Pasture Mixtures, Waite Institute.*

Two pasture mixtures sown in the autumn of 1932, consisting of (1) *Phalaris tuberosa* and Dwalganup subterranean clover, and (2) Perennial rye-grass, *Phalaris* and Dwalganup subterranean clover, were subjected to the following fertilizer treatments replicated in the form of a Latin square in 1933: (a) unfertilized, (b) superphosphate, 2 cwt. per acre applied in autumn, (c) sulphate of ammonia, 1 cwt. per acre in autumn and again in spring, and (d) superphosphate, 2 cwt. per acre + sulphate of ammonia, 2 cwt. per acre as above.

The plots were grazed two to four times each year, according to seasonal con-

ditions. Areas of pasture were cut prior to grazing for determination of yield and botanical composition. Yields of hay were also measured by cutting the herbage from a protected quadrat area on each plot at the end of seasonal growth.

Although the application of nitrogen increased the yield of dry matter per acre over that of the unfertilized plots, it was much less effective in general than phosphate in this regard throughout the term of the experiment (1933–37). The effect of the nitrogen in all years was markedly to stimulate the sown grasses, annual grasses, and weeds at the expense of the clover, which, on the other hand, was stimulated by the phosphate applications.

Where both nitrogen and phosphate were added, the two pasture types did not respond in the same way. That from which perennial rye-grass was excluded responded to the nitrogen and produced significantly greater yields than with phosphate only, the increase over the five years being 16·1 per cent. The mixture containing perennial rye-grass, however, yielded slightly less when both fertilizers were applied than when phosphate only was given, under both grazing and hay-cut conditions. The difference is to be found in the much greater yields of miscellaneous herbage in the former pasture than in the latter, where greater development of the perennial rye-grass following the nitrogen application took place at the expense of the *Phalaris tuberosa.*

The trend in this pasture of the two sown grasses was from perennial rye-grass dominance in the first two years to *Phalaris* dominance, but where nitrogen was applied the latter species remained the subordinate one.

(6) *Investigations on the Grazing Value of Pastures.*

(*a*) *A Comparison of Top-dressed Natural and Seeded Pastures at the Waite Institute.*

For the purpose of comparing the relative grazing values and carrying capacities under normal grazing conditions of top-dressed sown and natural pastures, two areas, each of 2·5 acres, were sown in May, 1934, with a mixture of Wimmera rye-grass and early subterranean clover, and two similar areas with a mixture of *Phalaris tuberosa* and early subterranean clover. Two more areas of each type of pasture were established in May, 1935, which, together with four areas of top-dressed natural pasture, made twelve blocks available for the experiment, with 10 acres of each pasture type. These areas were top-dressed similarly in each year of the experiment with 2 cwt. of superphosphate per acre.

Previous experimental work had shown that the top-dressed natural pasture would carry 1·6 sheep per acre and the sown pastures approximately double that number. From a uniform flock of Merino wethers 16 were selected to graze the 10 acres of natural pasture, while two lots each of 32 sheep were allocated to the sown pasture areas, thus giving a stocking rate on the seeded pastures of 3·2 sheep per acre as compared with 1·6 on the natural pasture.

The grazing commenced on 1st July, 1935, and concluded on 5th July, 1938, and throughout the experiment the flocks were rotated over the four areas of their respective pasture with a week between each rotation, so that normally each block was spelled for three weeks at the completion of a grazing cycle.

On 21st July, 1936, four sheep of each flock were chosen at random to comprise a fourth group which grazed, in turn, on each type of pasture.

Prior to the conclusion of seasonal growth in 1936 and 1937, but not in 1935, one-half of each block was cut for hay, and was fed back to the sheep on each corresponding pasture during the late summer and autumn months. The value of this procedure is shown by the fact that during the period of hand-feeding in 1937 and 1938 the severe loss of weight which occurred in the similar period of 1936 was completely prevented.

A comparison of the seasonal growth in each year was obtained by cutting on each block six areas of seven feet square protected from grazing by quadrat frames. The method of evaluating the three types of pasture has been by comparing the live-weight increases of the sheep, their wool weights and values and, in addition, the yields (1) of herbage from the enclosed quadrats, and (2) of hay from the half of each block in 1936 and 1937.

Although the mean live-weight increase during late autumn and winter was significantly higher in each year for the natural pasture flock than for the Wimmera rye-grass + subterranean clover flock, which, in turn, was significantly greater than the *Phalaris* + subterranean clover group, the superiority of the sown pastures is amply demonstrated when the total live-weight increases for the term of the experiment are considered. The figures for natural pasture, Wimmera rye-grass + subterranean clover and *Phalaris* + subterranean clover flocks are 1,018·5, 2,305·5, and 2,199·9 lb. respectively, so that the gain in live-weight for both sown pastures is more than twice as great as for the natural pasture. The superior nutritive value of the sown pastures over the natural pasture is shown by the significantly greater mean live-weight increase of the sheep from 21st July, 1936, until the completion of the experiment on 5th July, 1938.

No differences in wool weight, quality or value of the fleece per head were evident at the 1936 shearing, but in 1937 the mean weight and value of the fleece of the natural pasture and Wimmera rye-grass + subterranean clover flocks were greater than that of the *Phalaris* + subterranean clover and rotational flock. The quality of the wool was finer on the sown pasture.

The superiority of the sown pastures is again demonstrated when wool weight per acre is considered, owing to the greater carrying capacity.

The Wimmera rye-grass + subterranean clover pasture has in all three seasons produced a greater yield of herbage in the protected quadrat areas than has either the natural pasture or the *Phalaris* + subterranean clover pasture.

The superiority of the Wimmera rye-grass + subterranean clover pasture is also shown in the yield of hay in 1936, when it was nearly double that of the other pastures, and in 1937, although in this year the differences were much less marked.

(*b*) *A Comparison of Top-dressed Natural and Seeded Pastures at Kybybolite.*

An investigation similar to that at the Waite Institute is being conducted in co-operation with the Department of Agriculture at the Experimental Farm, Kybybolite, where pastures of Wimmera rye-grass + midseason subterranean clover and *Phalaris tuberosa* + midseason subterranean clover are being compared with top-dressed natural pasture. Four blocks of each type of an approximately total equal area are being grazed in rotation with a standard flock of comeback ewes, and additional sheep are introduced as considered necessary during the period of flush growth in spring and early summer. The standard flock consisted originally of 40 ewes, but subsequent deaths have reduced the numbers to 35 on the natural pasture and 39 on each of the sown pastures. The live-weights of the ewes are recorded each month.

The pastures have been compared on the basis of their grazing returns, wool yields and values, the mean yield of herbage representing the seasonable production cut from five enclosed areas each of 1 sq. metre, the live-weight gains of the sheep of the basal flock, and their lambing figures and rate of lamb development.

The carrying capacity for the first three years of the experiment, as based on the grazing data, is similar on all three pasture types, the figures being 3·40, 3·83, and 3·68 sheep per acre for natural pasture, *Phalaris* + subterranean clover, and Wimmera rye-grass + subterranean clover respectively.

The mean weight and value of wool per head in 1936 and 1937 were greater in both sown pasture flocks than in the natural pasture flock, but at the 1938 shearing the mean weights of all flocks were not significantly different.

The yield of herbage of the Wimmera rye-grass + subterranean clover pasture was superior to the other pastures in 1936, while in 1937 both sown pastures surpassed the natural pasture. In 1935 the three types did not differ significantly in yield.

The higher nutritive value of the sown pastures as compared with the natural pasture has been shown by the greater mean weight attained by the sown pasture flocks throughout the first year of the experiment. The mean live-weight of the sown pasture flocks has been consistently higher than that of the natural pasture flock. The percentage lambing has been higher each year on the sown pasture plots, and the rate of development of the lambs, as measured by the mean daily increase in live-weight, was significantly greater in the Wimmera rye-grass + subterranean clover flock than the other two in 1938. Detailed results at both centres are given in Table 13, on page 116.

(7) *Investigations on Pasture Management.*

The trend in southern Australia is from natural to seeded pastures. There is, however, a lack of knowledge relating to the management of pastures. A trial designed to measure at least some of the attributes of a typical sown pasture under

different forms of grazing management was therefore commenced at the Waite Institute in 1936.

An area of approximately 8 acres was established in May, 1936, to a seeds mixture of 1 lb. Wimmera rye-grass, 5 lb. *Phalaris tuberosa,* and 5 lb. early-flowering subterranean clover. The pasture was top-dressed with 2 cwt. superphosphate per acre, this dressing being repeated annually. Following uniform treatment in its seeding year, the pasture was subdivided into 54 separately-fenced one-seventh acre plots.

Although designed for five years, the data already collected indicate the profound influence of grazing management not only on the growth of the pasture, but also on the yield of hay and botanical composition. The data for the seasons 1937–38 appear in Table 12 on page 114. Whereas the mean annual production of the pasture in cwt. per acre for the two seasons 1937–38 decreased from approximately 37 cwt. to 32 cwt. as the stocking rate was increased from 2 sheep per acre to 6 sheep per acre, the production decreased from approximately 37 cwt. to 29 cwt. as the grazing cycle was reduced from a 9-weekly cycle to a 3-weekly cycle. In other words, lengthening the grazing interval from 3 weeks to 6 or more weeks has had a much greater effect on the increase of production of the pasture than decreasing the stocking rate. In fact, the data show that more herbage has been produced under a stocking rate of 6 sheep per acre where the pasture has been grazed at intervals of 6 and 9 weeks, than with only 2 or 4 sheep per acre at a grazing interval of 3 weeks.

Analyses of the botanical composition of the pasture in September, 1938, indicate that reduction in the proportion of grass to clover in the pasture follows an increase in the frequency of grazing, and is also brought about by cutting the pasture for hay in mid-spring. This reduction in yield and content in the pasture of the dominant grass species (*Phalaris tuberosa*) is followed by an increase in the proportion of clover and subsequently of weeds.

There are strong indications that the adoption of a much longer period between grazings than is usually employed is likely to have considerable advantages, not only in increasing the carrying capacity, but in maintaining the equilibrium between the grasses and clover in the pasture. The experiment so far has shown that 6 wethers per acre can be pastured throughout the year, and without injury to the pasture where the grazing interval is 6 to 9 weeks, whereas 6 wethers per acre is definitely in excess of the capacity of the pasture where the grazing interval is reduced to only 3 weeks; it is necessary to remove the sheep from this rotation at the end of February. On the other hand, plots receiving the same grazing treatment, that is, carrying 6 sheep per acre and grazed once every 3 weeks, on which the spring flush of herbage is conserved as meadow hay and fed back during the dry summer and autumn period, can maintain their quota until the following growing season.

Section of management trial on a pasture of *Phalaris tuberosa* and subterranean clover showing the effects of different grazing treatments, 1938.

3. PLANT BREEDING AND GENETICS.

(1) *Cereals.*

(*a*) *Wheat.*

The aim of the wheat-breeding programme at the Waite Institute is the production of varieties adapted to the special requirements and range of South Australian soils and climate and superior to existing varieties in yielding ability, in resistance to drought and disease, and in baking quality.

Since the issue of the last Report three new wheats, Waria, Seewari, and Gluwari, have been named and made available for distribution to farmers. Tested out for some years in yield and observation plots at the Waite Institute and at various country centres, these new wheats have given satisfactory results, and, it is hoped, will be of benefit to the farming community.

Waria is a cross between Hard Federation and Gluyas, made in 1928, with the object of combining the drought-resistance and yielding ability of Gluyas with the strength and comparative shortness of straw and baking quality of Hard Federation. Waria is a mid-season wheat, and produces short, strong straw, and medium to large grain of good baking quality. It outyields either parent, and has yielded equal to or better than the standard variety Ranee 4H, which it resembles in many respects. During the last season (1938–39) it has demonstrated its ability to withstand dry conditions in Mallee areas.

Seewari is a late mid-season variety developed as an early selection from the late-maturing variety Sepoy. On heavy soils it has outyielded all other varieties and strains. It has short, strong straw, and medium to large grain of average baking quality.

Gluwari is a selection from Early Gluyas. It is one of the two surviving strains isolated from some 500 head selections made from a field of Early Gluyas at Minnipa in 1928. It possesses stronger straw than Gluyas, and is capable of outyielding that variety. It is an early to mid-season variety. Its grain is similar to Gluyas, and of fair baking quality only.

The first table shows the yields of these wheats expressed as bushels per acre and as a percentage of the standard variety for the years 1936–38.

These new wheats are now in the multiplication stage, bulk fields being devoted to increasing the supply of seed for distribution. It is proposed to test them further to determine the extent of their adaptability to wider regions of the State.

Since high yielding ability is incompatible with high baking quality of grain, the farming community will not sacrifice yielding ability for quality—under present conditions they are not compensated for so doing. There is, however, evidence to show that several new crossbreds will meet requirements for a high-yielding wheat of baking quality above the average of South Australian wheat varieties now in use. These crossbreds, with others of promise, are in their last stages of testing in yield and observation plots. Country centres have been established at

Yields of New Crossbred Wheats—Waria, Seewari, and Gluwari.

			1936.		1937.		1938.	
Variety.	Strain Number.	Plots sown at	Yield bush. per ac.	Per cent. yield of Nabawa.	Yield bush. per ac.	Per cent. yield of Ranee 4H.	Yield bush. per ac.	Per cent. yield of Ranee 4H.
Waria	36–18	Waite Institute	45·40	119	38·90	97	36·28	109
		Yurgo	—	—	21·10	94	20·30	101
		Tarlee	—	—	28·70	107	13·13	113
Seewari	33–101	Waite Institute	47·16	121	33·20	89	42·12	111
		Yurgo	—	—	21·40	96	20·33	101
		Tarlee	25·30	104	28·20	105	13·57	116
Gluwari	32–32	Waite Institute	—	—	—	118	37·00	117
		Yurgo	—	—	—	—	17·91	89
		Tarlee	—	—	—	—	13·57	116

Yurgo, Tarlee, and Pallamana for the sowing of replicated field trials, while observation plots exist at about twelve different centres representative of the varying types in the range of South Australian soils and climate.

The results of field trials with new crossbreds tested in replicated yield plots at the Waite Institute during the years 1936–38 are found in Tables 14, 15, and 16, on pages 118–120.

Crosses involving the varieties Nabawa and Ford with Hard Federation give the best indications of a high-yielding, good quality wheat suitable for average South Australian conditions.

Resistance to disease is an important aspect of the wheat-breeding work. A wheat definitely resistant to any or all of the major diseases of wheat, more especially stem rust, and possessing the agronomic characters desirable in South Australian wheats would attain favour immediately, the present demand being for dependable disease-resistant wheats. Natural infection of both stem and leaf rust occurs at the Waite Institute to a more or less sufficient degree each year, facilitating immensely the work in breeding for rust resistance. Realizing the importance of these two diseases in respect to the damage done annually to the Australian wheat crop, disease-resistance work has been concentrated on this particular problem.

The American variety Hope, resistant to rust, bunt, loose smut, and flag smut, but of no commercial use in itself in Australia, has been the variety used in most of the crosses in this direction. By careful selection for resistance where possible, and attention to other essential agronomic characters, a number of strains of promise have reached the yield trial stage. The following table gives a list of crossbreds tested last season, which show up particularly well as far as yield and rust-resistance are concerned in comparison with the standard Ranee 4H. This commonly-used variety was badly affected by the rust epidemic experienced last season at the Waite Institute.

Crossbred Wheats Tested at Waite Institute During 1938.

Strain Number.	Strain or Variety.	Yield. bush. per ac.	Per cent. yield of Ranee 4H.	Days to Heading	Stem Rust 0–5	Leaf Rust 0–5
37–76	Nabawa x Hope	49·16	133	115	0	0
37–321	Gluyas x Hope	44·25	130	119	0+	2
37–319	Gluyas x Hope	43·99	130	118	0+	2
37–77	Nabawa x Hope	43·73	128	114	0	0
37–318	Gluyas x Hope	41·66	126	114	0+	2
37–326	Gluyas x Hope	42·96	125	118	0+	2
37–297	Early Gluyas	41·40	120	113	4	3
37–316	Gluyas x Hope	39·07	114	114	1	2
37–21	Nabawa x (Sepoy x Hope)[1]	42·70	113	118	0+	0
37–34	[Gluyas(w) x Hope][2] x Nabawa	39·33	100	124	0+	0
—	Ranee 4H	35·45*	100	116	5	5

* Mean of all check plots. Percentage yields determined as per cent. of mean of adjacent checks.

Rust-resistant strains in the fourth to eighth generations, and of a more complex nature involving four or five varieties, are also available for selection for yielding ability.

Artificial inoculation is necessary for bunt and flag smut infections and all crossbred, especially rust-resistant, material is infected with both bunt and flag smut as it comes into the advanced stages, so that any strain displaying resistance to these two diseases will not be overlooked.

An experiment to show the effect of stem and leaf rust on the yield and other characteristics of wheat was carried out during each of the two seasons, 1937–38 and 1938–39. The results indicate that loss in yield of grain due to stem and leaf rust infection may at times be considerable.

The results of the experiment carried out in the season 1937–38 were of particular interest because of the prevalence of leaf rust and the absence of stem rust. Severe infection of leaf rust reduced the yield of a susceptible variety (Ranee 4H) by 14·15 per cent., reduced the bushel weight of the grain by 1·2 lb., and reduced the average weight of individual grains by 8 per cent. The nitrogen content of the grain was reduced from an average of 2·869 per cent. to 2·673 per cent. Experimental loaves baked from samples of Ranee 4H wheat from the different treatments showed an average reduction in loaf volume from 578 c.c. to 510 c.c. for the standard bake, and from 708 c.c. to 640 c.c. when Nymalt improver was added. Spraying with colloidal sulphur, the method used to control both stem and leaf rust, had no measurable effect on the yield of the resistant strain (Gluyas x Hope) used.

During the 1938–39 season both stem and leaf rust were prevalent to a marked degree. The two varieties used were Dundee and Ford, Dundee being susceptible and Ford partially resistant to the two rusts. The results conform with the previous year's experiment in respect to yield as shown by the following figures:

Treatment.	Av. yield in bush. per ac. Dundee.	Ford.
Sprayed throughout	52·11	49·94
Sprayed to first appearance of stem rust	48·85	49·68
Sprayed from first appearance of stem rust	46·76	46·51
Sprayed from just after first appearance of stem rust	45·14	42·06
Unsprayed	42·17	41·52

(*b*) *Barley.*

In an effort to produce a smooth-awned feed barley, promising material from a cross between Cape Barley and a smooth-awned barley of Russian origin has been carried on to the yield trial stage. Ten strains, all of the smooth-awned type, and possessing agronomic characters equal to Cape, are now being tested for yielding ability.

(*c*) *Peas.*

The development of an early-maturing type of field pea for use in the drier areas of the wheat belt from crosses between the White Brunswick field pea and the varieties Crossbred D, White Arir, and Lemaire has reached the stage of these three crossbreds being tested out in replicated yield trials.

(2) *Pasture Plants.*

(*a*) *Phalaris tuberosa.*

From the parent plants described in the previous Report, four main strains were selected, these final selections being planted out as seedlings and randomized with propagants from the original parent strain to allow interpollination and the multiplication of seed of an improved type.

This pedigree strain was then sown down in a field sward trial as against commercial *Phalaris tuberosa,* and is being tested as an improved pasture type.

(*b*) *Perennial Rye-grass.*

Experience with perennial rye-grass since 1925 indicates that the Waite Institute is on the border-line of successful maintenance of this valuable plant. The limiting climate of winter rainfall and summer drought render it peculiarly suitable for the breeding of a strain of perennial rye-grass showing early flowering and superior winter growth. With this objective, approximately 20,000 single plants derived from seed collections throughout Australia and New Zealand and several European countries, were planted in the field in 1932. These plants were subjected to three heavy grazings during each of three growing seasons. In 1935 120 of the best plants were selected, transplanted to a new area of ground, and for five years were subjected to a critical yield trial, together with observations on date of flowering, growth form, fertility, and rust-resistance. On the basis of these yield results and observations further selections were made in 1937 and 1938, and superior plants allowed to intercross within canvas enclosures.

Seed from four combinations of intercrossed plants has been sown at the Waite Institute in a sward trial for comparison with four commercial strains. Sward trials have also been sown at two country centres.

(*c*) *Prairie Grass.*

Prairie grass (*Bromus unioloides* H.B. et K.) is a species of considerable value in the high rainfall and the irrigated areas of South Australia, because of its ability to make vigorous growth throughout the relatively mild winter. It has been studied over a period of four years, both as spaced plants and in grazed swards. As a result of observations on some seven thousand single plants, eight genetically stable types have been recognized. The data on the source of the material were insufficient to permit a complete determination of the factors responsible for the origin of these types, but it is certain that the biotic factor has been a major influence in the segregation of certain of the strains recognized. For example, the common commercial type is erect and is unsuited to grazing, characters which would be segregated in the course of continued commercial seed production. On the other hand, certain of the material from permanent pastures shows a widely divaricate habit and suitability for grazing.

Tests have also been conducted on the resistance of the various types to infection by the smut-forming fungus, *Ustilago bromivora*. Of the 54 lines tested, 42 were predominantly of the five types susceptible to smut infection, and 12 lines were of the three resistant types. It has been shown that infection of susceptible types can be completely and conveniently prevented by the use of mercurial dusts.

During 1937–38 the grazing value of representatives of the eight types recognized has been assessed by the use of replicated grazed swards. These were sown at the Waite Institute and on a reclaimed irrigated swamp of the lower Murray River. At each centre the highest yields were given by the two representatives of Type VI, a robust but poorly tillered type, immune from smut infection. Further work will be confined to the representatives of this type.

During the course of the work it has become evident that no strain of this species possesses the growth-form characters found in strongly perennial species. Seedling regeneration is essential for the replacement of senile plants, and good management is necessary for the maintenance of the species in the sward. Nevertheless, the winter production of the species fully warrants its use, particularly as a constituent of temporary leys in areas of good rainfall.

(*d*) *Subterranean Clover.*

The work on *Trifolium subterraneum* was designed to assess the value of types already segregated and named by various State Departments of Agriculture rather than to select or breed new types. The most striking difference between these strains is the variation in maturity. For example, in 1935 Dwalganup commenced to flower 99 days after seeding, while Tallarook commenced after 166 days. Be-

tween these limits is found a continuous range of maturity types. Significant positive correlations were found between lateness of maturity on the one hand and yield, percentage of leaf, and number of racemes on the other. Nevertheless, within any particular maturity group, superior types exist.

A close correlation was found to exist between the percentage of flowers setting seed and the climatic conditions (as expressed by evaporation from a free water surface) during the flowering period.

The interaction between the number of flowers and the percentage abortion of flowers controls the failure or success of any variety in a particular climatic zone. According to the length of the growing season, early, mid-season, or late types will eventually gain dominance if a mixed seed sample be sown.

Up to 1938 the work has been conducted on spaced plants. A sward trial may show that the differences in yield between early and late strains is much diminished when the population is dense.

(*e*) *Barrel Medic.*

The outstanding legume in South Australia is subterranean clover, but it is now obvious that its use is restricted to areas with an effective rainfall season of six months or more, and to soils neutral to acid in reaction.

Investigations have therefore been directed towards the use of an alternative species adapted to areas of lower rainfall and to soils with a high lime content. Of those species now naturalized or that have been introduced for testing, barrel medic (*Medicago tribuloides*) appears outstanding; for example, it has developed and reseeded itself well on a typical Mallee soil at Pallamana, where the average annual rainfall is 12 inches, and where subterranean clover will not persist.

The species is closely related to burr medic, but it does not possess the hooked spines on the seed pod so objectionable in that species. A wide variation, however, exists in the length of the spines in different naturally occurring strains.

A collection of 46 strains of barrel medic was made in 1937 and 1938. These have been sown with the objective of selecting productive strains of improved burr type.

(*f*) *Creeping Lucerne.*

The sowing of lucerne, either alone or as a constituent of pasture mixtures, for grazing purposes in the wheat belt of South Australia has increased rapidly during recent years. There is a growing appreciation of its drought-resistance and summer grazing value in areas of 12–20 inch rainfall. Its value would, however, be much improved if it were not so subject to damage by intensive grazing.

Creeping types without a marked crown, and characterized by the production of underground or rhizomatous stems are occasionally found in established lucerne fields. A collection of creeping types has been made and grown for a number of years at the Waite Institute. One strain (Tusmore) is outstanding in its ability to spread and form a dense sward, but it sets seed very poorly.

A breeding programme initiated in 1934 with the objective of producing a commercial creeping type of lucerne adapted to grazing conditions is now in progress. Crosses between the Tusmore strain and Hunter River were made in 1934. Later generation selections from this cross, together with selections from intercrosses and open pollinated isolations of different creeping types, have been used for the production of cross pollinated seed of diverse creeping types. Selection work is being continued, and sward trials have been established at country centres.

(*g*) *Strawberry Clover.*

Strawberry clover (*Trifolium fragiferum* L.) is gaining in importance on the rendzina soils of the South-East of the State. Unfortunately much of the commercial seed is of inferior genetic constitution, giving a close, small-leaved turf of low productivity. Many lines collected directly from pastures are large-leaved, vigorous, and with a greater stolon development and lateral spread than the commercial forms. The breeding programme involves the production of a strain of one of these better types for pasture purposes.

4. INVESTIGATIONS RELATING TO SOIL EROSION AND PASTURE REGENERATION.

(1) *Yudnapinna.*

Preliminary investigations into soil erosion and pasture regeneration problems were begun at Yudnapinna Station, in the north-west pastoral area of the State, in 1938.

The average annual rainfall at Yudnapinna is 7·50 inches, but the precipitation is extremely variable. The most typical soil is probably a sandy loam, while the vegetation is broadly classed as Myall scrub with bluebush and saltbush.

Four quadrats of from one to four acres each have been selected at eroded centres, and are to be charted in detail thrice yearly, and the effects of cultivation, the sowing of arid herbage species, burning, and protection from rabbits and/or sheep, upon the revegetation of the area are to be recorded. A trial of approximately fifty dry-land pasture species, selected on the basis of performance at Pallamana, and of a number of species of trees and shrubs was commenced. In addition a soil and ecological survey is to be undertaken by the Division of Soils.

(2) *Pallamana.*

Seeds of a large number of native and introduced plants were collected from 1936 onwards for the purpose of determining their value for propagation in and regeneration of the arid pastoral areas. These were grown at Pallamana, where their establishment, growth, and persistence could be determined. The annual rainfall at this centre is approximately 12 inches per annum, and although the amount is greater and the distribution more reliable than that of the pastoral areas, it was realized that the test would serve the purpose of indicating which species

might be of value under still more severe climatic conditions. The area was prepared as fallow, given an application of superphosphate at the rate of 1 cwt. per acre, and seedlings of 200 different species, raised in seed boxes at the Waite Institute, were planted over the period from June, 1937, to September, 1938.

The establishment of most native and naturalized species was excellent under the conditions of planting, but the majority of those introduced from other parts of the world failed to survive. The greatest development was made by the native saltbushes and bluebushes and allied genera.

The outstanding types of saltbush were the perennial species *Atriplex vesicarium, A. paludosum, A. stipitatum* and *A. nummularium,* and a species introduced from South Africa, *A. capensis,* together with *A. semibaccatum* and *A. leptocarpum.* The latter two species differ from the former upright, woody, perennial types in being prostrate in growth form, much less woody, annual, and in re-establishing themselves better from seed. Another species, *Rhagodia spinescens,* developed as vigorously as did the saltbushes. Of the bluebushes, *Kochia Georgei, K. brevifolia,* and *K. tomentosa* were the outstanding species, although their development was not comparable with that of the perennial saltbushes.

Of the grasses tested, several perennial species survived two summers, but of these perennial veldt grass (*Ehrharta calycina*) and millet grass (*Oryzopsis miliacea*) were foremost in their development, while of the annual species, Wimmera rye-grass (*Lolium* spp.) and Mediterranean grass (*Schismus barbatus*), grew vigorously, and seedlings appeared in large numbers in the following season.

Of the annual legumes tested, barrel medic (*Medicago tribuloides*) proved most successful, both in vigour of development and in annual regeneration from seed, while lucerne of either the erect or creeping type proved itself adapted to the area. Other species exhibiting vigorous development include *Bassia brachyptera, Atriplex elachophyllum, Enchylaena tomentosa,* and *Tetragonia arbuscula.*

(3) *Stabilization of Drifting Soil.*

An experiment designed to investigate the ability of various species to grow on and to reclaim an actively drifting sandhill was conducted at Pallamana in 1937. Rye-corn, barley, and Wimmera rye-grass were drilled in strips running the length of the experimental area, while lucerne, peas, and a mixture of Dwalganup subterranean clover, cluster clover, barrel clover, and burr clover were broadcast singly or with evening primrose in plots running across the drill rows. Counts carried out twelve weeks after seeding revealed that, except in the case of rye and barley, the establishment of all species was low, none exceeding 14 per cent. That of the rye was 45 per cent., a figure significantly greater than the 39 per cent. of the barley. The severe drift which took place subsequent to this time exposed the roots of the young plants to extreme desiccation. The rye plants proved capable of some degree of resistance, and a cut made at the end of November showed the yield of grain to be 192·5 lb. per acre, while that of barley was only 0·6 lb. per acre, and the yields of all other species nil.

Moreover, the rye-corn proved capable of stabilizing the sand, and that blown from the barley and Wimmera rye-grass strips mounted up and was held fast by the rye stubble.

Because of the failure of various pasture species to persist when sown on an actively drifting area, and in view of the outstanding value of rye-corn in the stabilization of it, an experiment was designed in 1938 to investigate the establishment, persistence, and productivity of various herbage species when seeded on an area where the drift had been temporarily controlled by a seeding of rye-corn in the previous year.

Two similar areas were sown with the following species of legumes and non-legumes, sown either alone or in combination: early subterranean clover, lucerne, barrel medic, perennial veldt grass, Wimmera rye-grass, evening primrose and Mediterranean grass. A satisfactory establishment of between 33 and 44 per cent. resulted in the case of the first five species, while that of the latter two was very low. Subsequently, however, a heavy mortality of plants occurred, and in October, when a sample cut was taken, only barrel medic and lucerne contributed in any substantial manner to the yield.

The experiment will be continued during 1939, when counts of plant survival and re-establishment will be made and yield data obtained.

An alternative species to rye-corn for the stabilization of sandy areas subject to extensive drift was found to have proved very successful on an area near Murray Bridge. The plant is pyp grass (*Ehrharta villosa*), which spread from three original plants and rapidly covered a considerable area by virtue of its rhizomatous growth form. This grass is capable of development at all times of the year, but its main growth is made in the spring and summer. A selected area of pyp grass was mown in 1938, and an experiment commenced to test the effect of varying levels of superphosphate and a seeding of evening primrose and barrel medic on its yield and grazing value.

The establishment of both species was low, being 16·6 per cent. for barrel medic and 1·3 per cent. for evening primrose, and was not increased by the application of superphosphate.

(4) *Pasture Establishment.*

An experiment designed to supply information on the establishment, persistency, and productivity of various combinations of leguminous and non-leguminous plants on a typical Mallee soil at Pallamana was commenced in 1938. The plots were sown on fallow, with and without wheat as a cover crop, which was either cut during the season to simulate grazing or allowed to proceed to maturity, and with two levels of superphosphate, ¾ and 1½ cwt. per acre. The species sown were barrel medic, early subterranean clover, lucerne, Wimmera rye-grass, evening primrose, perennial veldt grass, and a mixture of three saltbushes, creeping, slender-fruited, and *Atriplex campanulatum.*

Counts of plant numbers carried out twelve weeks after seeding revealed an excellent establishment of Wimmera rye-grass and a satisfactory establishment of all other species except evening primrose and saltbush. The presence of the cover crop had no deleterious effect on plant numbers, nor did the higher level of superphosphate result in any increase.

Adjacent to this experiment strips of lucerne (2), early subterranean clover (2), barrel medic (2), *Medicago confinis* (1), and *M. obscura* (1) were sown, and across their length were introduced in duplicate perennial veldt grass, creeping saltbush, evening primrose, Wimmera rye-grass, and a mixture of all four species together with Mediterranean grass, thus giving 25 different legume-non-legume combinations. The establishment counts, which were very comparable with the above experiment, ranged from 65 per cent. of the sown viable seed of Wimmera rye-grass to 33 per cent. in the case of barrel medic, while evening primrose and creeping saltbush gave figures as low as 3 per cent. and 10 per cent. respectively.

5. SHEEP-RUGGING INVESTIGATIONS.

The suggestion that rugging flock sheep would improve wool production originated in this State in 1934; since then it has been the subject of numerous investigations in many parts of Australia and in New Zealand. Climate, soil composition, and the nature of the pasturage are important factors in wool production, and there is no doubt that the conditions under which an experiment is carried out are largely responsible for the results obtained. Investigations were commenced in 1935 to determine the effect of rugging on the wool and body weight of sheep under the conditions existing at this Institute.

Forty Merino wethers of uniform age, weight, and wool production were used. Jute canvas rugs were put on 20 of the sheep after shearing in September, 1935, the remainder forming a control group. All the sheep were run together and managed as an ordinary farm flock.

The sheep were weighed each month, and in the second year of the trial staple length measurements were recorded for 10 sheep of each group every time they were weighed. It was found that the rugged wethers were always slightly heavier than those unrugged, but at no period was the difference in weight greater than 3 lb. per head.

The rate of growth of the wool as determined by staple length measurements was uniform throughout the year for both groups.

The wool production of the rugged and control sheep is given in the table below, and shows that there was no significant difference in the weight per head of greasy or of scoured wool between the two groups of sheep. The estimated "yield" of scoured wool obtainable from the greasy wool was slightly higher for the rugged sheep.

Mean Weight per Head of Greasy and Scoured Wool.
(Weight in lb.)

	1936.		1937.		Mean of 2 years.	
	Rugged.	Controls.	Rugged.	Controls.	Rugged.	Controls.
Greasy Wool	12·31	12·62	11·90	12·14	12·10	12·38
Scoured Wool	6·40	6·36	6·41	6·51	6·40	6·43

6. BOTANICAL SERVICE.

The strictly botanical work of the Institute is concerned mainly with the accurate identification of plants, the building-up and care of the Herbarium as a necessary adjunct to identification work, and a certain amount of attention to matters concerning the Arboretum, which has an important demonstration value.

An advisory service in plant identification and information is supplied to the Minister of Agriculture, through whose Department most enquiries from primary producers come; also to the Minister of Afforestation, and to any other persons who wish to avail themselves of the service. Most of the enquiries relate to poisonous plants, weeds and their control, and to pasture plants. Over 300 specimens were dealt with in 1938. Several requests for seeds of native plants have also been met.

A named series of native plants of importance in areas liable to soil erosion has been mounted in glass cases for permanent display on the walls of the Ranson Mortlock Laboratory.

Identifications have been made of large numbers of plants of importance to the field work of the Entomological Department, the Soils Division, and the workers on problems of soil erosion.

Weeds recently recorded for the State are perennial ragweed (*Ambrosia psilostachya* D.C.), the African thistle (*Berkheya rigida* Thunb.), Mexican poppy (*Argemone mexicana* L.), *Oxalis flava* L., and the long-fruited wild turnip (*Brassica Tournefortii* Govan); the last is already a serious noxious weed in the Murray Mallee, where it was probably introduced from Western Australia. Bindweed (*Convolvulus* spp.), though not new, is a very troublesome weed.

Illustrated articles on important weeds (viz. *Euphorbia terracina* L. and *Marrubium vulgare* L.) were published in the Journal of Agriculture of South Australia.

The collecting and growing of seeds of native plants suitable for eroded areas have been continued.

Plant Physiology

The increase of the yield of crops and the improvement of the quality of plant products depend ultimately upon control of the growth and development of the individual plant, and such control is possible only on the basis of a fundamental

knowledge of the physiology of the separate metabolic processes in the plant and of growth and development as a whole. Investigation in plant physiology at the Institute has continued to centre firstly upon growth and physiological aspects of the ontogeny, or development, of plants; and secondly, upon nitrogen metabolism.

(1) *Growth Studies.*

Ontogeny is characterized by continuous changes, not only in total size of the plant, but in the proportion of the parts and in their chemical composition and physiological attributes. The understanding of growth involves extensive study of these changes and of their interrelations under various sets of conditions. The most obvious feature of ontogeny is the progressive change in dry weight of the plant. Investigations on the rate of this change, the relative growth rate, were described in the last Report. The first graph further illustrates this work in showing how the proportions by weight of the various parts of an annual plant vary with time during the growing period. It is seen that there are three phases of growth, in which growth of leaves and roots, stems, and finally inflorescences, respectively preponderate.

Since the issue of the last Report attention has turned to the changes in chemical composition of the parts, especial consideration being given to the distribution of nitrogen within the plant. Nitrogen is taken up mainly during early growth (see second graph), accumulating first in the roots, leaves, and stems. At about the time of flowering, however, nitrogen ceases to be taken in by the plant as a whole, and commences to migrate from the leaves into the developing inflorescence. The declining relative rate of uptake of nitrogen by the plant implies a progressive fall in percentage nitrogen content of the various parts on a dry-weight basis throughout practically the whole of the growing period.

Especial interest has centred on the factors determining the changing amount of nitrogen in the leaves. Among these have been recognized the following:

(1) Variation in the initial concentration of nitrogen in the external medium, and its decline with time as the plant grows.
(2) The rate of growth of the leaves and their capacity for nitrogen uptake.
(3) The development of other parts of the plant which act as sinks for nitrogen, the outstanding example being the inflorescence. In the case of individual leaves, those developing higher on the plant may derive some of their nitrogen from the lower ones.
(4) The capacity of the root system for nitrogen uptake, which may decline as the plant ages.
(5) Internal changes in the leaves leading to a decrease in the rate of protein synthesis or an increase in the rate of hydrolysis.

Increasing knowledge of the relative importance of these possible factors is being gained by more intensive studies at present in progress. The recognition of

the factors has also enabled an analysis to be made of the effects of varying nutrient supply on the nitrogen content of the leaves.

This work on chemical changes in the plant during growth, of which no adequate summary can be given in the space available, has rendered possible an advance in the analysis of growth rate and of the changing rate of metabolism with age. Two aspects of metabolism have been studied during ontogeny: the first of these is the unit leaf rate or net assimilation rate, which is the net amount of dry matter synthesized by each gramme of dry matter in the leaves in one day; the second is the respiration rate, which is measured by the amount of carbon dioxide gas given off by each gramme of dry matter in the leaves per hour. Respiration rate has been studied because it is a useful index of the general level of metabolic activity of the leaves. Both these quantities, so expressed on a dry-weight basis, decline during the greater part of the growing period. The conclusion has been reached, however, that this decline is due largely to the decrease in the proportion of living to non-living matter in the leaves as they grow older. The best measure so far available of the living matter of the leaves is the total amount of protein that they contain. This is possibly inadequate, since there may be inactive storage proteins as

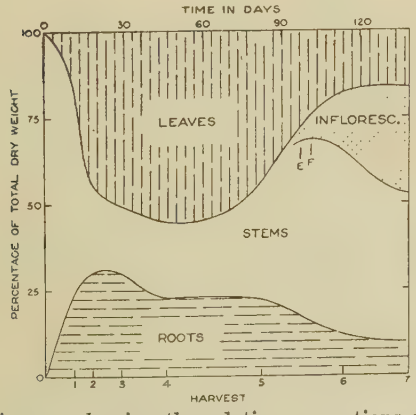
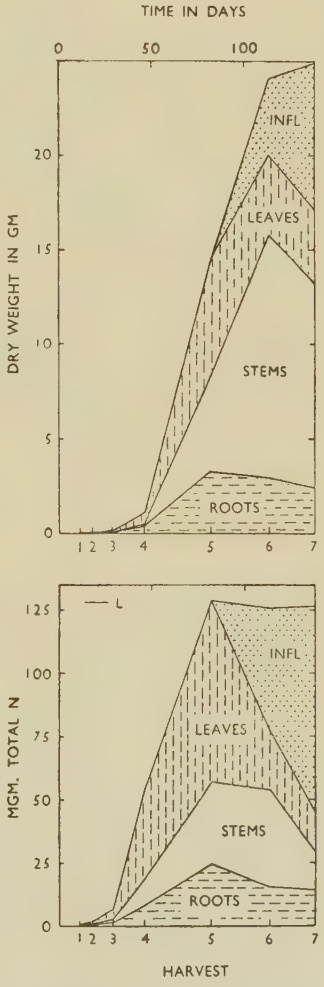


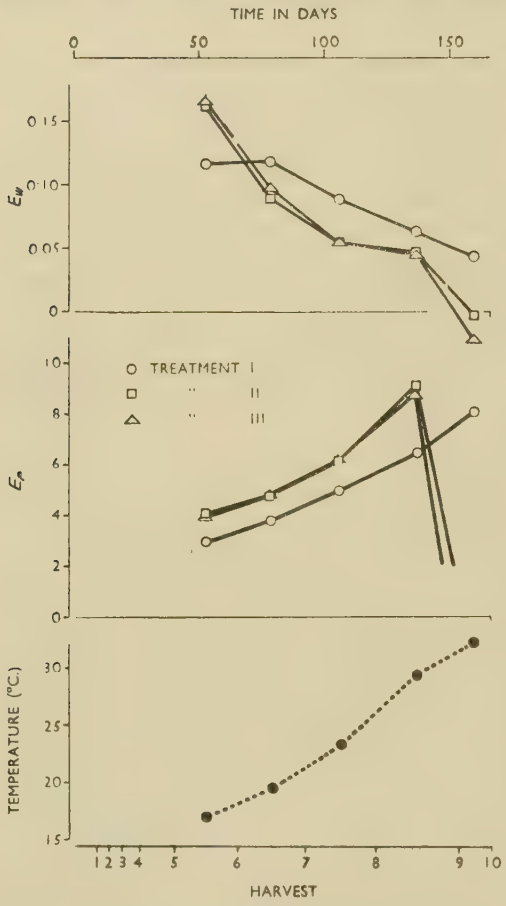
Diagram showing the relative proportions of parts throughout the life of the oat plant. The ungerminated seed has been arbitrarily classed as stem. E indicates time of exsertion of inflorescences and F time of flowering.

(Reproduced by courtesy of the *Australian Journal of Experimental Biology and Medical Science*).



Dry weight and absolute nitrogen content of the parts of the oat plant plotted additively. L indicates the magnitude, on the scale of ordinates, of the amount per plant of the nitrogen supplied in the nutrient solution.

well as those constituting the seat of metabolic reactions. However, when net assimilation rate is expressed on the basis of the amount of protein in the leaves instead of on a dry-weight basis, it is found that the variations are largely correlated with variations in the environmental temperature. This can be seen in the set of data illustrated in the third graph.



Net assimilation rate on a dry-weight basis (E_W), and on a protein-nitrogen basis (E_P) for oats with three phosphorus treatments, together with the mean maximum daily temperatures for the appropriate inter-harvest periods. The treatments were I, 0·0093 gm. P per pot; II, 0·121 gm.; III, 0·486 gm.

It seems probable that under constant environmental conditions the net assimilation rate on a protein basis would remain fairly constant over a considerable portion of the growing period. If this can be substantiated by further work it is possible that the assimilation rate so expressed may represent a quantity of considerable value in comparing the efficiency of growth of different varieties and species of plants.

(2) *Studies in Nitrogen Metabolism.*

Studies on the nitrogen metabolism of pasture grasses have been continued in collaboration with the Department of Botany of the University of Adelaide. The first of these studies has led to the conclusion, referred to in the previous Report, that, if a position of balance between proteins and amino-acids be assumed, then this position is a function of the water content of the tissue. This relationship has been further studied, since it represents an important aspect of the water relations of the plant. It can be explained by various hypotheses, one being that the curve relating the steady-state concentration of proteins and amino-acids is concave to the amino-acid axis. Evidence has now been obtained suggesting that the curve has, in fact, this form. Changing water content could also affect the protein balance if it caused a change in the proportion of

different amino-acids. It has been found that the amount of one amino-acid, cystine, does not always vary directly with that of the other amino-acids in the leaves. Whether, however, this is an important factor in the protein-amino-acid balance is not yet known.

It has also been shown that the amounts of amino-acid nitrogen and amide nitrogen in the leaves are dependent on the amount of ammonia, but it was not possible to show that either of these relationships was affected by the water content as was that between proteins and amino-acids.

(3) *Physiological Studies on the Tobacco Plant.*

This work has been continued on behalf of the Council for Scientific and Industrial Research. The quality of cured tobacco is to a considerable extent determined by the chemical composition of the leaves at the time of ripening. This composition is dependent on the developmental history of the leaves. To elucidate the factors determining the composition at the time of ripening, a study has therefore been made of the physiological ontogeny of the leaf and the drift in its composition, especially in relation to the development of the plant as a whole. Particular attention is being paid to the nitrogen, organic acid, and sugar contents, as these compounds all appear to be important in the determination of quality. The first stages of this work are now approaching completion, but it has been felt desirable to postpone any detailed account of the results until a full survey is given in the next Report.

Plant Pathology

The maintenance of an advisory service in plant pathology to the Departments of Agriculture and Woods and Forests, helps to keep workers at the Institute familiar with the general position regarding the occurrence of plant disease in the State of South Australia.

Since the publication of the last Report the bacterial canker disease of tomatoes (*Aplanobacter michiganense*), which is new to South Australia, has been found locally. This occurrence follows closely upon the finding of "leaf mould" of tomatoes, which was first observed in South Australia in 1935. Both outbreaks followed shortly after similar appearances in the Eastern States.

On roses two uncommon fungi have been recorded, viz. *Botryosphaeria dothidea* (Moug. et Fr.) Ces. et de Not., and *Coniothyrium fuckelii* Sacc. The former causes a scab on briar rose canes, and the latter a canker at the point of budding.

Rust (*Puccinia boroniae*) on the sweet-scented boronia (*B. megastigma*), which was first described by Hennings on the related species of boronia (*B. spinescens*), has now been found in South Australia. It was observed several years ago in Victoria (Jour. Agric. Vic. *30*: 389), where there was evidence to show that

several types of seedlings were resistant to the disease. Vegetative propagation from such selected types promises to furnish the best means of control for this serious disease.

An interesting case where vines were apparently struck by lightning at Watervale has been described (Reprint No. 237).

"Pink rot" in celery (*Sclerotinia sclerotiorum*), although known to be present in the State for several years, has become more common over the last three years. This increase can be attributed partly to unsatisfactory methods for disposing of infected debris, and partly to the short rotational system which is practised.

Cylindosporium concentricum Grev., an interesting fungus causing a leaf spot of cauliflowers, was observed for the first time in South Australia. Besides attacking the leaves it produces discoloured patches on the curd, and reduces its market value.

The fungus *Stereum sanguinolentum,* identified through the kind services of the Imperial Mycological Institute, is common on debris on the forest floor, and has been observed on standing diseased *Pinus radiata* in a forest plantation.

In addition to the work entailed in the provision of advisory services in South Australia, investigations on certain major or widespread diseases as described below have been undertaken. These accounts do not cover two important classes of plant diseases, viz. those like the "grey speck" disease of oats, which are due to the inability of the plant to secure adequate amounts of certain minor elements from the soil, and virus diseases. Investigations on these two classes, the "minor element deficiency" and virus diseases, are described elsewhere in this Report.

(1) *Cereal Diseases.*

Wheat is the most important crop plant in South Australia, and, as was stated in the last Report, it is the diseases which affect the underground portions of the plant that are economically the most important. The causes of these root diseases, considering the associated parasites, are very varied. The nematode, *Heterodera Schachtii,* and several fungi, including *Ophiobolus graminis, Rhizoctonia solani, Fusarium* spp., *Helminthosporium sativum,* and others, have been found separately or associated together on diseased plants. Since each of these organisms has been proved capable of pathogenic activity under some circumstances, the presence of mixtures on diseased plants makes a diagnosis, which defines diseases in terms of the associated pathogene, rather an arbitrary procedure. Still, in spite of these difficulties, the view has gradually emerged that the fungus *Ophiobolus graminis* is of particular importance in South Australia, so that attention has been concentrated on it and on the disease "take-all", which it causes.

(a) *"Take-all" of Wheat.*

The general features of this disease and the plants which may act as hosts were referred to in the last Report.

Diseased and healthy shoots from grapevine showing the symptoms of a disease resembling court noué.

Briar rose scab [*Botryosphaeria dothidea* (Moug. et Fr.) Ces. et de Not.] on left young, on right older lesions.

The study of the problem is being approached from three angles, each complementary to the other: viz. by pot experiments, field experiments, and studies on the growth of the fungus itself. In the pot experiments, which have been carried out under glasshouse conditions in crocks large enough to grow plants to maturity satisfactorily, several problems of technique apart from those normally associated with pot work under glasshouse conditions had to be resolved. In all experiments where the objective was to determine the effect of variable soil conditions on the development of the disease, it has been found necessary to have two complete series of pots, one of which was inoculated, the other serving as a control. At the same time, by using factorial designs, a study of the effects of varying several different soil factors, either in chemical or physical status, separately and in combination, has been possible, and the number of pots necessary for adequate replication, manageable. Methods of inoculation, type, and quantity of inoculum are all important in determining when and how severely the disease develops, and these have been standardized.

Another difficulty lies in the choice of suitable terms in which to describe the relative severity of the disease resulting from the differential treatment of pots.

It is true to say that under favourable circumstances and with a sufficient volume of the right kind of inoculum favourably placed, it is possible to kill off seedlings at an early stage of growth. The number of seedlings so killed or the degree of blackening of the underground parts affords some measure of the severity of the disease. On the other hand, this seedling phase of the disease, which is known to farmers as ''take-all'' itself, is not as common or economically nearly as important as the ''whiteheads'' or ''haydie'' phase. Actually, difficulty has been met with in securing the symptom of ''whiteheads'' consistently in a typical form. In default of securing these completely developed symptoms, the best measure available appears to be the weights of dry grain produced per pot.

The need to recognize the importance of the ''whitehead'' phase of ''take-all'', with the consequent necessity to grow experimental material to maturity for its proper study, needs emphasis.

In designing the pot experiments two lines of approach have been followed. The basis for the first approach is provided by field observations of manurial trials, which have shown that the incidence of ''take-all'' is related inversely to rates of dressings of superphosphate. One such series of observations, showing the reduction in ''take-all'' incidence with applications of superphosphate, is dealt with on pages 25–26 of the Report of the Waite Institute, 1925–32, and similar results have since been obtained from other field plots treated in the same way. In interpreting these results it was considered that the effects of superphosphate in reducing ''take-all'' might simply be due to a beneficial effect on the growth of wheat in soils well known to be responsive to dressings of superphosphate.

In the first line of approach, then, the result of treatments whose primary effect is believed to be the stimulation of the growth of the wheat plant, is being studied.

In the second place, though obviously the two approaches cannot be separated by any hard-and-fast rule, the object of the variations in soil treatment is to make conditions more or less suitable for the activity of *Ophiobolus* in the soil. In this connection the effects of variations in the energy materials available in the soil and the consequential variation in the flora, as well as variation in the physical states of soil, have received attention.

The field work in experimental plots commenced in 1935 with observations on the incidence of "take-all" in a series of plots designed to test the varietal response of wheat to superphosphate and sulphate of ammonia (Waite Institute Report, 1933–36, page 162), and plots on the same ground have been observed each year since. In these plots, besides the original treatment differences shown above, efforts were made in subsequent years to secure plots with different states of tilth.

In 1937 steps were taken in conjunction with the Council for Scientific and Industrial Research and the State Department of Agriculture to initiate field plot experiments at two country centres: one in the Murray Mallee area, and one on Eyre's Peninsula. The plots are being established on land suspected to be badly affected by "take-all". They are primarily designed to test the effects of practicable rotation and management systems, and the effects of certain soil amendments under field conditions. It is intended that they should be maintained for a period of 5–10 years.

The study of the survival of *Ophiobolus* in the soil under field conditions is being continued at three centres. It has become clear that apart from differences due to soil and climate factors the substrate in which the fungus has developed is important. In accordance with this, the original technique has been modified in such a way as to develop the fungus in the soil in a form more closely comparable to that which occurs naturally in the field.

In the laboratory work has been done on the nutrition of the fungus under conditions of pure culture in liquid media, and it is being extended to studies on growth of the fungus in the soil.

(b) *Barley Diseases.*

The field trials designed to test the effectiveness of seed treatment in the control of covered smut (*Ustilago hordei*) and stripe (*Helminthosporium gramineum*), which were referred to in the previous Report, were continued in 1936, and the results have been published (Reprint No. 196). The results revealed that the organic mercurial preparations used gave satisfactory control of both diseases. "Formalin" (40 per cent. Formaldehyde) 1–320 and copper carbonate were both less useful.

(2) *Gummosis (Dieback) in Apricots.*

A progress report on this disease has been published (Reprint No. 241). It has been established that the disease is caused by a fungus which invades the wood

and can destroy the bark tissues. The principal port of entry is through wounds, especially those which expose the wood. The disease can be disseminated with the pruning saw. The systematic position of the causal fungus is not yet clear. On affected branches the fungus produces fructifications of a type which would place it in the form genus *Cytosporina*. The development of an ascomycetous stage on old fallen branches is suspected.

(3) *Grapevine Disease.*

Attention is being given to a disease in grapevines, the symptoms of which vary a good deal, but in general conform to those described for court noué and allied diseases as they occur in Europe. It develops most frequently on old-established vines of wine variety grapes growing close to Adelaide. The symptoms are most evident in early spring, and it is usual for them to be confined to the shoots of one "arm". Affected shoots are much reduced in length, and the leaves in size. Distortion of the leaves with mottling and necrosis is also common. Severely affected shoots frequently die as the season progresses. In less severe cases a degree of apparent recovery of the affected shoots sets in.

In both types of cases, however, the vigorous growth of the shoots and leaves from the unaffected "arms" hides the defective shoots, producing an impression of recovery.

The expression of symptoms on vines presumed to be slightly affected is apt to be variable from year to year, a moderately severely affected "arm" sometimes producing comparatively healthy shoots the following year. No readily detectable organism—fungus, bacterium, or insect—has been associated consistently with the trouble. Experiments are in progress to test two possible alternatives: (1) that the disease is infectious and transmissible, i.e. virus in nature; (2) that it is due to an inability of the vine to secure adequate supplies of certain minor elements from the soil.

(4) *Rind Blemish in Oranges.*

Work on this subject was started in 1938 as part of the programme of the Citrus Preservation Technical Committee, a committee of the Council for Scientific and Industrial Research. The blemishes under consideration develop on oranges kept in cool storage, but those with which the well-defined "green" and "blue" moulds develop are not included. The particular aspect being studied is the question of how far fungi present in some of these lesions are responsible for their development.

As a first approach the question of early association of fungi with the rind when it is still apparently sound is being studied. The technique employed is essentially that which Baker and Wardlaw in Trinidad (Ann. Bot. N.S. *I*, 59, 1937), and Bates at the Mazoe Experimental Station, Southern Rhodesia, have used. The survey to establish the degree of so-called "latent infection" in oranges

in different citrus-growing areas has recently been extended to oranges grown in other States besides South Australia.

(5) *Miscellaneous Investigations.*

The field trials using chloropicrin for the control of eelworm (*Heterodera marioni*) in the soils of tomato glasshouses have been completed. The results show that when suitably applied, chloropicrin is an effective material for reducing infestation of tomatoes by eelworm in the season following its application. The results of this work are being prepared for publication.

An investigation of the reasons for the failure of tick beans grown for seed purposes on the reclaimed swamp soils of the Lower Murray Valley area is in progress. The failure is most marked during the later periods of growth, when a high proportion of the crop fails to produce seed.

A start has been made with the investigation of fungus diseases of radiata pine (*P. radiata*), which is grown extensively in forest plantations in South Australia. With the co-operation of the Woods and Forests Department inoculation experiments to test the pathogenicity of fungi isolated from diseased trees are in progress.

Entomology

The work of the Department of Entomology falls into three sections: research into insect pests, an advisory service to the Department of Agriculture, and teaching within the Faculty of Agricultural Science of the University.

It is the object of the research programme to establish accurate and full information about the insect pests of the State. The work is not restricted to insects which attack agricultural crops in the narrow sense; it includes forestry pests, those of horticultural crops, and also deals when necessary with those of medical and veterinary importance. Efforts are concentrated on a few major problems at a time, but general observations are also made on other matters as they arise. The work relates primarily to problems of importance in South Australia, but in certain cases the pest concerned is of economic significance over a large part of Australia. Thus in the case of the lucerne flea and of thrips, the problems have been considered from an Australia-wide point of view. In the same way certain of the grasshopper studies at present in progress will cover the whole range of occurrence of these insects in Australia.

The first step in the study of an insect pest is to establish the main facts concerning its life history, food requirements and habits, but these are not in themselves sufficient to explain its possibilities as a pest. In this connection studies are therefore made of the influence of temperature and humidity on the rate of development of the insect in the laboratory. Each insect has a characteristic and fairly narrow range of preferred humidity and temperature. In the active stages

of its life-history an insect is able, within limits, to select a favourable situation, even in an environment which may be generally unfavourable to it. The eggs, however, have not this ability, and for this reason physiological studies of this kind are made chiefly upon the eggs of insects. The data obtained are then used in defining the probable climatic and geographical range of the insect as a pest.

Attention has also been given in recent years to the definition of climatic zones in relation to the activities of insects, and particularly with regard to the influence of weather on insect numbers. The period of dormancy of the egg known as the diapause is also being considered. In order to undertake work of this kind several incubators with precise temperature control have recently been installed. These have proved to be capable of working for extensive periods at almost constant temperature, over a range from about 0–35° C.

The study of the fluctuations in the numbers of insects has led to fundamental studies on animal populations generally, the history of the increase in the sheep numbers of South Australia and Tasmania affording excellent examples of the way in which such populations are built up.

The Department of Entomology maintains contact with other entomological work in progress in Australia, and co-operates wherever possible with workers in these investigations. By similar co-operation it has been possible to undertake studies at the Waite Institute on certain problems of Australia-wide interest. Assistance has always been readily available from the various Divisions of the Commonwealth Council for Scientific and Industrial Research, and from the entomological services of the various States, and this has greatly facilitated the work of the Department.

In this Report discussion of the work of the Entomology Department will be limited to the following subjects:

1. Locust and grasshopper investigations.
2. Insects of agricultural crops.
3. Thrips investigations.
4. Forest entomology and timber pests.
5. Miscellaneous.

1. Locust and Grasshopper Investigations.

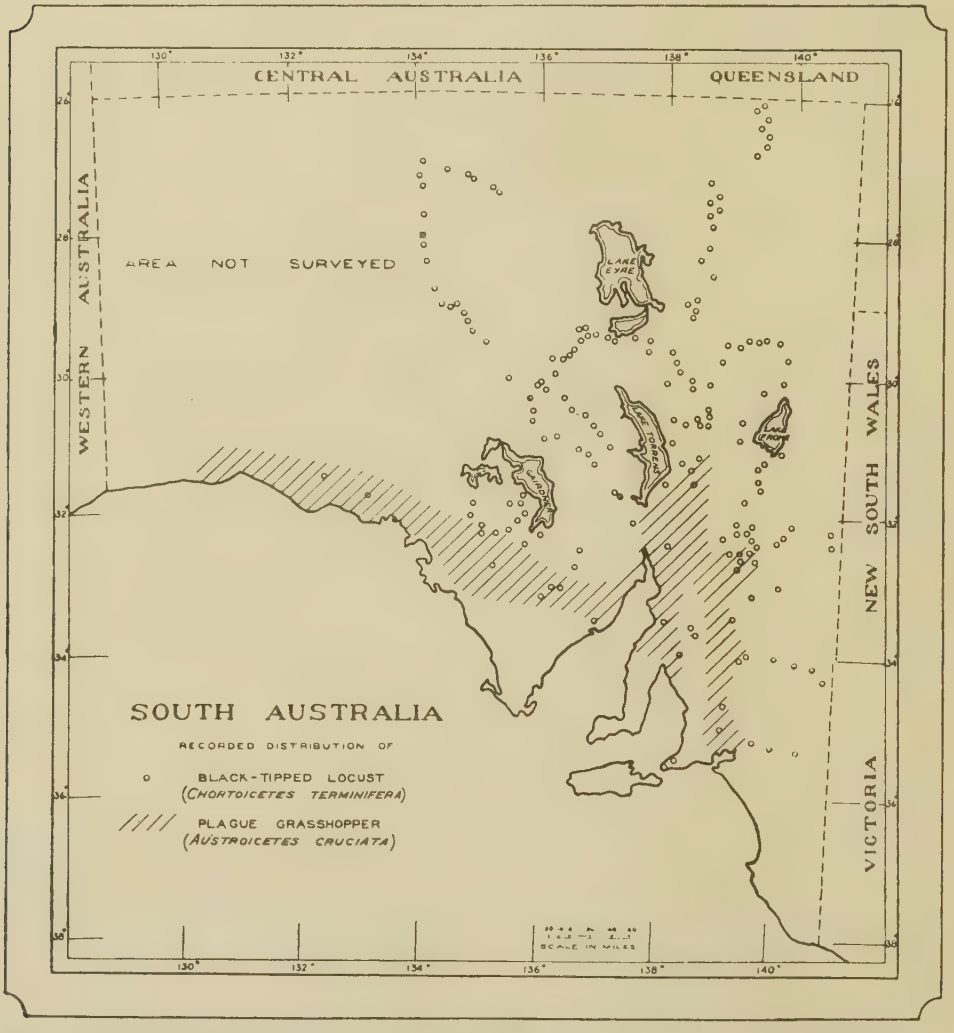
At the meeting of the Agricultural Council held in Perth, in September, 1938, the Council recommended that the Waite Institute be primarily responsible for research on *Austroicetes cruciata* throughout the Commonwealth, and additional funds were made available through the Council for Scientific and Industrial Research for an extension of the work now being done on *A. cruciata* at the Waite Institute.

During the past two years research work has been directed principally towards the problem of the two major species in this State, viz. the Australian plague locust

(*Chortoicetes terminifera* Walk.) and the small plague grasshopper (*Austroicetes cruciata* Saussure). Observations have also been made on certain other species of minor importance, notably *Phaulacridium vittatum* Sjöst., and *Austroicetes pusilla* Walk.

(1) *The Small Plague Grasshopper* (*Austroicetes cruciata* Saussure).

A major outbreak of *Austroicetes cruciata* occurred in South Australia in 1938. The severity of the damage was increased by the relatively dry spring and



Map showing recorded distribution of the Australian plague locust (*Chortoicetes terminifera* Walk.) and area where swarms of the small plague grasshopper (*Austroicetes cruciata* Sauss.) may occur.

the consequent shortage of feed when the grasshoppers were approaching maturity. The grasshoppers were also present in economic numbers in 1936 and 1937.

As a result of field surveys during the three years the distribution of *A. cruciata* in South Australia is now known with considerable precision (see map). Swarms are restricted to a definite climatic belt agreeing approximately with the area in which the ratio of rainfall to evaporation (P/E index) exceeds 0·5 during four to six months of the winter. Within this climatic belt soil type and vegetation influence the distribution of swarms. In the mallee areas where sandy soils predominate swarms may occur only in restricted situations; in areas characterized by firm, compact soils swarms may be widespread.

A. cruciata is weakly gregarious; it migrates only relatively short distances, and its geographical distribution is stable. In these respects it resembles the plague grasshoppers in other parts of the world, notably *Melanoplus* spp. in North America, *Gomphocerus sibiricus* and *Chorthippus scalaris* in Siberia, and *Arcyptera microptera* in Northern Europe. *A. cruciata* differs from the true migratory locusts. The latter are strongly gregarious, and undertake long migratory flights. Their geographical distribution is not stable; periodically they swarm out from the endemic areas and occupy, temporarily, extensive regions normally free from plagues.

In South Australia the active stages of *A. cruciata* are present from August to November. There is only one generation each year. Although the young grasshoppers crowd on certain patches of favoured food there is, at first, no definite tendency to be gregarious. Later, for a short period during the fourth and fifth instars, the hoppers may mass together into bands and migrate over short distances. At no stage are the bands so dense as those formed by *Chortoicetes terminifera,* nor is the urge to migrate so well developed. Indeed in seasons when food is particularly abundant in the vicinity of the hatching areas the gregarious and migratory habits may fail to develop.

The adults tend to form loose swarms. Although these swarms may cover many square miles they never achieve the density which occurs with *C. terminifera.* Even in loose swarms adults of *A. cruciata* seem to retain a large measure of individual action. Consequently large mass movements and mass migrations never occur. Under certain conditions of temperature and humidity the grasshoppers fly strongly and more or less continuously, but there seems to be no organization about the flights. Different individuals may fly in different directions at the same time, and the same insect may fly in different directions on successive flights. Consequently very little advance over the countryside occurs with the swarms. Under the influence of a prevailing wind the flight may achieve direction over a period of days. No precise information is available on this point, but it is considered that the maximum movement of a swarm is not likely to exceed fifteen miles.

The numbers of *A. cruciata* fluctuate from year to year. In the past observations on this aspect have been inadequate. Records, when they occur, usually

refer to damage done to crops or pasture. The amount of damage is influenced by other factors besides the density of the grasshopper population. Hence past records are apt to be confusing. Observations tabulated by Hunt establish the presence of major outbreaks in 1874, 1877, 1896, 1910, 1911, 1912, and 1913. From references in the newspapers in the early years of the colony there is some evidence that outbreaks of *A. cruciata* occurred in 1846 ("The Register", 9th Dec., 1846), 1858 ("The Register", 12th Dec., 1858), and 1871 ("The Register", 19th Dec., 1871). The absence of records for other years does not necessarily mean that outbreaks did not occur. In 1935 there was a major outbreak; the grasshopper was present in economic numbers during 1936 and 1937, and a major outbreak occurred in 1938.

The factors influencing the abundance and distribution of *A. cruciata* are being investigated. It has been shown that the egg stage is characterized by a diapause. This operates to prevent development during summer, and ensures that the active stages will be present during the spring—the one period of the year when food is likely to be adequate. Eggs collected from the field in the summer fail to develop when incubated; those collected in June hatch after about five days at 30° C.; they take longer at lower temperatures.

Field observations have established the presence of three parasites which prey upon the eggs of *A. cruciata*. The most important one is *Cyrtomorpha flaviscutellaris* Rob. (Bombyliidāe). In certain situations the larvae of this fly have been observed to destroy 25–30 per cent. of the grasshopper eggs. The small wasp *Scelio chortoicetes* Frogg. has been reared from eggs collected in the field. It has never been observed to be numerous. An unidentified larva of a beetle (Dermestidae) occurs rarely. The adult is not known. The influence of parasites on the numbers of *A. cruciata* is probably secondary to that of the physical environment and competition for food.

The success of control measures depends upon the efficient organization of the campaign. Poison bran bait is the most satisfactory material to use. The grasshopper belt is characterized by large holdings worked by relatively few men. Under these conditions chemical control measures are expensive and difficult to organize. It is hoped that further investigations may indicate ecological control measures which may be used against this pest.

(2) *The Australian Plague Locust* (*Chortoicetes terminifera* Walker).

Major outbreaks of *Chortoicetes terminifera* in South Australia have been recorded for 1890–91 and 1934–35; similar plagues probably occurred in 1844–45 and 1871–72. Swarms probably reached the wheatbelt in 1875 and 1917. The absence of records for other years does not necessarily mean that swarms were not about.

Field observations have shown that *C. terminifera* occurs as a solitary grasshopper from Cape Jervis in the south to Birdsville in the north (see map). Apparently this species has a much wider adaptability to climate than *A. cruciata*.

Although the locust occurs in restricted habitats over most of South Australia, swarms may arise only in certain zones. The limits of the outbreak area are determined largely by climate, but topography, soil type, and vegetation are also important.

The important factor inhibiting the development of swarms in the agricultural areas of South Australia is the nature of the winter. For several months of the year temperatures below or near the developmental zero are associated with a P/E ratio exceeding 0·5. In the semi-arid zone further north this condition does not occur; the insect is able to take advantage of the favourable conditions produced when rain falls in the summer.

There is considerable evidence that favourable weather for several successive years is necessary before a major outbreak (on a scale similar to that of 1934–35) can occur. Further work is necessary before the factors causing outbreaks are fully understood, but the broad principles are already clear. Swarms are likely to occur in the outbreak area when rain is adequate during the warm months of the year. Two or more seasons may be required to produce large or dense swarms. Similar conditions are required for swarms to develop in the intermediate breeding areas. For the outbreak to continue its development in the agricultural areas a season of comparative winter drought is required. This whole sequence is necessary for a major plague. The cycle may be broken at any point; when this occurs the incipient outbreak will be destroyed.

2. Insects of Agricultural Crops.

The lucerne flea and red-legged earth mite occupy the chief positions in this section. They have been dealt with fairly extensively in previous Reports.

The status of lucerne flea (*Smynthurus viridis* L.) as a pest remains largely unchanged. Observations on the incidence of the pest in the field have been continued, and control by spraying is under investigation.

The red-legged earth mite (*Halotydeus destructor* Tuck.) continues to increase in importance, more particularly in connection with market garden crops. Spraying trials to evaluate the most likely insecticides are in progress.

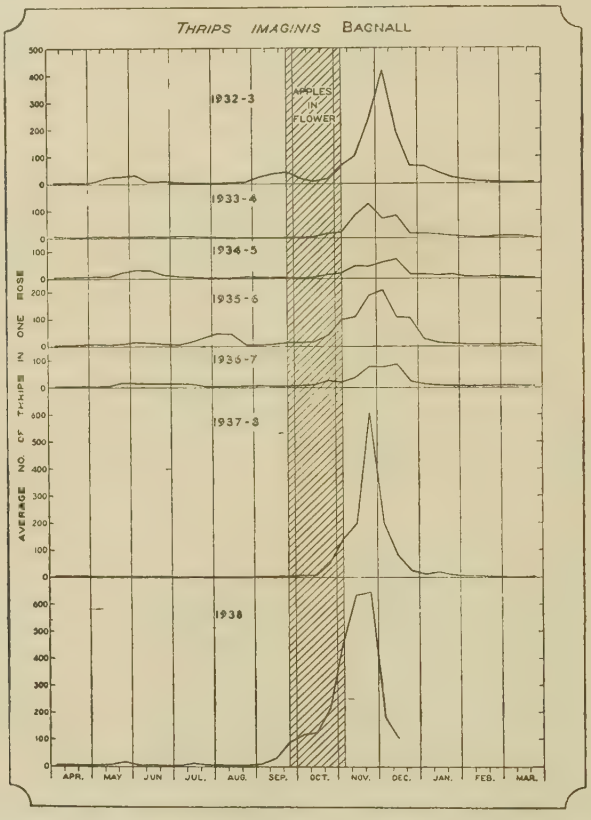
3. Thrips Investigations.

(1) *The Apple Thrips* (*Thrips imaginis* Bagnall).

Investigations of the problem of the apple thrips were discussed in the Report of the Waite Institute 1933–36, pages 60–63. During the past two years records of the numbers of *Thrips imaginis* in roses in the garden at the Waite Institute have been continued. The graph summarizes the data obtained from these observations since their inception in 1932. The shaded area represents the period during which the apple is in flower.

The striking feature of the population curve is the seasonal rhythm which it

displays. Experimental data provide an explanation for this rhythm. The developmental zero for *Thrips imaginis* is about 8° C. The prepupal and pupal stages cannot survive in soil containing less than about 10 per cent. of moisture. Pollen is necessary for the development of the immature stages and for the production of eggs.



Graph showing numbers of *Thrips imaginis* Bagnall in roses at the Waite Institute. The shaded area indicates the period when apples are in flower.

During the summer, dryness of the soil is the most important factor, tending to maintain the numbers at a low level. Temperature is too low for rapid multiplication in the winter. In the autumn temperature and soil moisture may be adequate, but food is not plentiful. In the spring all these factors are favourable, and multiplication is rapid. In certain years the big rise in numbers in the spring may coincide with the flowering of the apple, when the amount of fruit set may be considerably reduced. The conditions which favour an outbreak are an early or warm autumn followed by an early, warm spring, in which there are at least some hot days during the flowering period of the apple.

(2) *The Tomato Thrips* (*Frankliniella lycopersici* Andrewartha).

The tomato thrips is known to be a vector of the spotted wilt virus of tomatoes. This species was originally referred to as *Frankliniella insularis* by Morison. More recently it has been shown to be distinct from that species.

4. Forest Entomology and Timber Pests.

Information has been collected during recent years regarding the status of the various timber-infesting insects in this State. These concern mostly *Pinus radiata,* the chief commercial timber crop. In plantations this species seems to be little troubled by serious insect attack. In nurseries cutworms (*Euxoa radians*) and the wingless grasshopper (*Phaulacridium vittatum* Sjöst.) sometimes give trouble. The latter is common in some of the main pine plantation areas of the South-East of the State: these areas fall within the zone of cool, fairly moist climate, which the insect requires.

The black pine-bark beetle (*Hylastes ater* Payk.) occurs in the forest. It may be found in great numbers in the bark of fallen logs or even of prunings; it is found mostly in the parts in contact with the soil surface. These beetles can also be found in the bark of stumps, up to ground level. So far no injury to growing trees has been demonstrated locally.

The aphis *Pineus boerneri* occurs, but seems to be of limited significance, and to confine itself to trees below the general level of vigour.

The beetle *Ernobius mollis* L. is found to some extent in bark on dead standing timber, but chiefly in still-attached bark on structural timbers in mills and in the vicinity of the forest. The larvae feed at the junction of the bark and the wood, and produce characteristic irregular galleries, which channel the wood superficially. Beyond this they do not damage the wood; the adult beetles may perforate it in emerging from the pupal chambers.

Lyctus brunneus Steph., the powder-post beetle, does damage to included sapwood in hardwoods, particularly in furniture and interior woodwork.

The chief cause of damage to floorings and structural timbers in South Australia is the termite *Coptotermes acinaciformis.* Surveys by the Council for Scientific and Industrial Research in the Adelaide district have shown that it is extremely common, and is responsible for almost all termite damage there. It is also known to damage the lead sheaths of underground telephone cables, and reports of its damage to goods stored in cellars and basements of houses are frequent. Its work is completely concealed, and is particularly associated with local moist conditions, such as leaking waterpipes. Damage by it is encouraged by the unsuitable types of building construction often used in the past. The Division of Forest Products of the Council for Scientific and Industrial Research has now prepared specifications for termite-proofed foundations for houses; the extra construction involved is slight, and can be installed cheaply and effectively.

5. Miscellaneous.

In the previous Report a brief account was given of the wasp *Encarsia formosa* Gahan, material of which was obtained from the Division of Economic Entomology of the Council for Scientific and Industrial Research. This tiny wasp is a parasite in the scale-stage of the greenhouse white fly (*Trialeurodes vaporariorum* Westw.). Wasps were liberated in glasshouses in the vicinity of Adelaide, and established themselves very rapidly. They seem to have been completely successful in controlling the white fly. Instead of being a fairly serious problem in commercial tomato houses as in past years, white fly is now notably scarce. Reports indicate that the wasp is widely established in the tomato-growing areas, and that wherever white fly appears wasps soon keep it in check.

Among other insect problems that have received some attention are the poultry stickfast flea (*Echidnophaga gallinacea* Westw.), the larva of the Oecophorid moth *Philobota* sp. in lawns and pastures, and cutworms in nurseries and market gardens.

Soils and Agricultural Chemistry

1. SOIL INVESTIGATIONS.

(1) *Soil Surveys.*

The policy of the Division of Soils of the Council for Scientific and Industrial Research with respect to soil surveys was determined in 1927, when the first survey of an irrigation settlement was made as part of the Murray River Soils Investigations. The objective has been to complete the surveys of all the irrigated areas commanded by the waters of the Murray and the Murrumbidgee. The Waite Institute has provided the headquarters for this work. The Division of Soils itself was established in 1929.

At some time or other since 1927 field parties have been at work in Victoria, New South Wales, South Australia, and Tasmania. Very close contact has been maintained wherever possible with State Departments of Agriculture and Irrigation, and co-operative work has been particularly successful with Western Australia and Victoria. In addition close contact is maintained with the Commonwealth Research Stations at Griffith and Merbein, both of them well placed in the irrigated areas themselves.

With the exception of a relatively small area at Waikerie in South Australia, the field surveys in the established fruit-growing areas under irrigation were approaching completion at the end of 1938.

During 1937 and 1938 considerable attention was devoted to the group of settlements at Mildura, including Red Cliffs and Merbein, in addition to the old-established trust area at Mildura itself. The recognition of the importance of pasture production under irrigation and of the peculiar problems associated with

the watering and draining of heavy soils, resulted in a demand for soil surveys in the Kerang district of Victoria, and a unit of 54,000 acres was completed as a basis for future investigational and advisory work.

Further work in Victoria has been associated with the proposed irrigation of considerable areas to be commanded by the Yarrawonga weir and by arrangement with the State authorities concerned a soil survey party has been stationed at Cobram.

The soil survey of the horticultural areas of the Murrumbidgee Irrigation Areas has also been completed and the results published.

In Tasmania, surveys on behalf of the State Agricultural or Forestry services were conducted for some years from a headquarters in the University of Tasmania, at Hobart. This centre has been closed for the time being, and Tasmanian work will be directed from the Waite Institute. A considerable area along the north-east coast of Tasmania has been surveyed, and more detailed work conducted on 7,000 acres near Currie's River. The Tasmanian surveys have always proved of interest to the Forestry Department of that State, and at the request of the South Australian authorities soil surveys have been carried out and were almost completed by the end of 1938 in the areas devoted to afforestation in the South-East of the State. The forest areas at Mount Burr, Mount Gambier, and Penola have been examined, and progress reports have been made available to the Woods and Forests Department. The work has been planned, however, in such a way as to provide for a complete survey of the South-East, with respect not only to the requirements of afforestation, but also with respect to agricultural and pastoral development.

As a preliminary to the surveys in the Mildura areas and in the South-East of South Australia, aerial photographic surveys were carried out by the Royal Australian Air Force. The photographs have been used extensively by the surveyors, and have in fact proved to be indispensable for accurate work and for economy of effort.

(2) *General Soil Investigations.*

In addition to the detailed soil surveys above mentioned, broad-scale reconnaissance work has been undertaken from time to time. Such has included a rapid assessment of the areas proposed for irrigation in Tasmania, and a traverse of tropical Australia in the Kimberley region of Western Australia and in the Northern Territory. This latter traverse represents the third visit to tropical Australia for the study of soil conditions, two previous visits having been to Queensland, and including traverses west from Townsville as far as Cloncurry.

The Division has also taken an interest in the exploration of Central Australia, being carried out by Mr. Michael Terry, Dr. Madigan, and the Adelaide University's Anthropological Expeditions. From all these, valuable soil samples from remote regions of Australia have been received for our type collection. The

data arising from the examination of these samples in the laboratory were published during 1938.

Since the Report of 1936, laboratory work on the red-brown earths of South Australia has been completed, and a description of these soils has now been published. The most productive wheat-growing areas of the State are found on soils of this type, these soils being among the earliest developed for agriculture. Mechanical and chemical analyses of numerous representative profile samples have been included in the description. The soil of the experimental field of the Waite Institute belongs to this group, and detailed information regarding this profile is included in this Report (page 94).

Many soils have been examined for the presence of soluble salts. Injury to fruit trees at Port Augusta was found to be due to the presence of soluble salts in the surface soils. The amount of chlorides present in the injured leaves was unduly high, and an examination of the soils showed an accumulation of soluble salts. Suggestions to minimize the trouble have been made.

A number of New Guinea soils, which were formed as the result of the volcanic eruptions of 1937, have been examined and compared with older soils formed on similar parent material. In addition, at the request of the Department of Agriculture of New Guinea, analyses have been made of, and advice given on, a further series of about 40 soils.

(3) *Improvements in Laboratory Technique.*

Interest has been maintained in improvements in methods for the examination of soils. New methods of analysis are continually being investigated, and, where possible, suitable modifications made to adapt them for soils.

A technique for the separation of the clay fraction for silicate analysis has been worked out, together with details for the determination of silica, iron, aluminium, and titanium. More work is now in progress on another method, which offers possibilities for the micro-determination of these elements in clay.

The determination of soil reaction by means of the glass electrode has been investigated in considerable detail. The glass electrode is now used for all routine determinations of reaction, since it is free from the limitations and errors of the quinhydrone and antimony electrodes. Possible sources of error, such as those due to junction potentials and to failure to secure equilibrium between the soil and suspension unless mechanical shaking is used, have been recognized, and precautions taken for their avoidance. An electrometer valve potentiometer has been constructed, and this enables readings to be obtained directly in pH units. A routine method has been adopted for the determination of reaction, total soluble salts, and chlorine in a single soil suspension. Total soluble salts are determined by a conductivity method, and a cathode ray tube has been incorporated to replace the telephones as the null point detector.

The destruction of the organic matter in soils has been examined. Ignition

in a muffle furnace for two hours at 450° C. or for half an hour at 500° C., results in the removal of practically the whole of the organic matter.

Selenium has been tried as a catalyst in the Kjeldahl method for the determination of nitrogen. On account of its beneficial effect in reducing the time required for digestion, its use has been adopted in both soil and plant analyses.

Methods for the determination of minute amounts of the heavy metals are under investigation. The use of an extractive method of analysis based on dithizone offers a very valuable means for the separation of small amounts of these elements. Their subsequent determination may then be made either by chemical means (generally colorimetrically) or by means of the polarograph. Their determination by means of the latter instrument depends upon the interpretation of the current-voltage curves which are obtained when a small amount of solution is polarized by applying a gradually increasing voltage to the electrodes. One advantage of the polarograph is that it frequently permits the simultaneous determination of several metals in the same solution. It is particularly valuable for small amounts of zinc. While these separations have been worked out primarily for plant materials and fertilizers, their extension to soil analysis will be investigated.

In the analysis of plant materials destruction of the organic matter, by digestion with nitric, perchloric, and sulphuric acids, has been found to be of particular value, since it prevents loss of the minor elements. In ordinary methods of ashing a proportion of these constituents is retained in the siliceous residue. The perchloric acid method of digestion has also permitted the use of the more accurate Lorenz gravimetric method for the determination of phosphoric acid.

2. MINERAL DEFICIENCIES.

Investigations on mineral deficiencies have been confined primarily to the importance of several of the trace elements for normal plant growth. Conditions governing the absorption of some of these elements are being investigated by means of pot experiments and water cultures. A survey is also in progress in an attempt to determine the normal range of the amounts of such elements as manganese, copper, and zinc in plants. For this purpose a large number of samples of Algerian oats has been collected, representing crops grown on typical soils throughout the Central and Lower North, Yorke Peninsula, Murray Mallee, and Lower South-East. Both plant and soil samples have been collected, and it is hoped to be able to trace a correlation between the amounts of the minor elements present in the plants and those present in the soils. Improved methods have been worked out for the accurate determination of these elements in plant materials.

Fertilizers manufactured by modern methods tend to be much purer than those formerly in common use. On some soils this may be found to have an important effect over a period of years, since the soil may become depleted in some essen-

tial minor element. Samples have been obtained of a wide range of fertilizers commercially used in Australia, and these are being examined, by the polarographic method, for their less common constituents. Nitrogenous and potassic fertilizers have, in general, been found to have a very low content of heavy metals, whereas superphosphate, on the other hand, contains an appreciable amount of zinc. Most of this zinc appears to be derived from the original phosphate rock.

In collaboration with the Horticultural Branch of the State Department of Agriculture a disease of fruit trees at McLaren Flat is being investigated. A deficiency in the soil of one of the less common elements is suspected, and pot and field experiments are in progress.

(1) *Manganese.*

Interest continues to be centred in the practical application of the results of earlier investigations on this subject. The production and use of fertilizers containing manganese sulphate is extending. The bulk of the output goes to southern Yorke Peninsula, where the most important areas of manganese-deficient soils occur. However, an increasing amount is beginning to be used in the vicinity of Millicent. Manganese sulphate is usually marketed in a superphosphate mixture, each bag containing 28 lb. of manganese sulphate and 159 lb. of superphosphate. The following figures show the consumption of this mixed fertilizer for the last five seasons:

Season.	Tons.	Season.	Tons.
1934	290	1937	627
1935	388	1938	779
1936	481		

The use of manganese sulphate on southern Yorke Peninsula has not only led to increased yields, but has also made it possible to develop new country which had previously been regarded as unsuitable for crop production.

The field experiments at Corny Point on the response of barley to manganese sulphate have been continued by the State Department of Agriculture, and the results have been made available through the courtesy of Mr. L. J. Cook. During the last three years the average yield of the plots without manganese has been considerably higher than in the early years of the experiment. The average increase of yield due to 28 lb. of manganese sulphate per acre has dropped from 39 per cent. in the earlier period (1931–35) to only 9 per cent. for the last three seasons. Since the location of these experiments is changed from year to year, and they are planted on areas which have been subject to ordinary farm treatment in previous years, it would appear that the continued use of manganese sulphate has a considerable residual effect, permanently enhancing soil fertility on these deficient soils.

A number of soils has been examined by chemical methods for the determination of available manganese, but the results do not show any significant correlation with the known occurrences of manganese deficiency. Many mallee soils give un-

duly low values for the amounts of manganese extracted by ammonium acetate at pH 7 in the presence of hydroquinone, yet plants growing on them appear to be well supplied with manganese. For purposes of chemical diagnosis most reliance has still to be placed on either plant analysis or controlled pot experiments.

At the request of the State Bank certain mallee soils from the West Coast have been examined for manganese deficiency. Pot experiments showed that these soils could furnish sufficient manganese for normal growth, and that additions of manganese produced no increase in yield.

(2) *Copper.*

Copper has become of increased agricultural significance, since its importance as one of the minor element deficiencies responsible for the development of the fatal malady "coast disease" in sheep was demonstrated by the Animal Nutrition Laboratory of the Council for Scientific and Industrial Research. Copper deficiency in field crops was recognized at Robe in 1937, and field and pot experimental work has been carried out on this subject. Much of this work has been done in association with the Animal Nutrition Laboratory. The deficiency occurs on a highly calcareous soil, apparently identical with the Currie Calcareous Sand of King Island, derived from wind-blown sea shell fragments. Wheat and oats fail to make normal growth on this soil type, although rye can be grown successfully. The symptoms of the disease correspond with those described for *Urbarmachungskrankheit* ("reclamation disease" or "yellow tip") of Northern Europe. The plants exhibit a characteristic loss of turgor, the tips of the older leaves bending back on themselves and drooping. The tips of the newly-formed leaves become greyish-yellow and die without unrolling. Other leaves may show chlorotic areas along the margins extending from the tip towards the base of the leaf. In severe cases growth of the tiller is completely checked and no ears emerge. Numerous new tillers are formed, but these develop similar symptoms, and the tips die while the base of the plant remains green. Where ears are formed they are characterized by a whitish appearance, and there is little or no grain formation.

The natural pasture on these calcareous soils is usually composed of inferior annual grasses such as hare's-tail grass (*Lagurus ovatus*) and Madrid brome grass (*Bromus madritensis*). Legumes are generally scarce or absent, and the early attempts to establish superior pasture species failed.

Pot experiments have shown that copper in these soils exists in an unavailable form. Partial sterilization of the soil, by autoclaving, increases the availability of the copper, and oats grown on autoclaved soil make normal growth quite free from disease. On analysis, an increased uptake of copper was found. In other pots the applications of copper sulphate, at rates of 28 lb. to 2 cwt. per acre, showed that even the lightest dressing produced normal growth in oats and prevented the disease. Further pot experiments showed that the degree of saturation of the soil with water had little effect on the availability of copper. Applications of copper

sulphate did not give any increase in yield with rye, and it would appear that this plant can obtain the whole of its copper requirements normally from this soil.

Analyses of the crops grown in the pot experiments have shown a surprisingly small increased uptake of copper, even from heavy dressings of 2 cwt. per acre. The effect of soil reaction on copper uptake is being further investigated.

In experiments conducted in co-operation with the Animal Nutrition Laboratory, the comparative resistance of different plants and the symptoms produced by copper deficiency have been studied. Several species were grown in pot cultures of Robe soil, copper sulphate being applied at rates equivalent to 0, 10, and 80 lb. per acre. Rye-corn, carrot, lettuce, beetroot, and turnip under these conditions showed no definite deficiency symptoms, and gave no greater yields with the application of copper. *Avena strigosa,* a resistant variety of oats from Europe, was slightly influenced by copper application, but compared favourably with rye in its resistance to the deficiency. The yields of peas, lucerne, and onion were found to be increased to a small extent by the copper treatment, but in untreated pots they showed no pronounced symptoms. During the early stages of growth tomatoes showed some leaf symptoms, but these disappeared later in the season, and the final yields of treated and untreated pots did not differ significantly. It is suspected that under the conditions existing in the pots copper becomes more readily available with higher temperatures later in the season, and this, together with the ideal growing conditions, is regarded as the cause of the apparently greater resistance of plants to the deficiency when grown under glasshouse conditions.

A pot culture experiment was conducted with subterranean clover in the Robe soil to determine the effect of copper and of iron. The copper treatments were equivalent to 0, 10, and 80 lb. copper sulphate, and the iron treatments to 0, 28, and 112 lb. ferrous sulphate per acre. Iron prevented the early symptom of paleness and death of leaves, but the untreated plants recovered early (August). It was at this period that the effect of copper became pronounced. The copper treatment prevented the yellowing and more erect habit of growth that was developing in the control plants, and produced a greater yield at the September harvest. This co-operation with the Animal Nutrition Laboratory has been extended to field experiments at Robe. In these experiments copper sulphate was applied at seeding to wheat, oats, and rye, at six levels ranging from 0 to 112 lb. per acre. Maximum yields of wheat and oats (grain and straw) were obtained with 14 to 56 lb. copper sulphate per acre. Rye was found to grow normally in these areas without the application of copper, and gave no greater yield with any copper treatment. Copper sulphate applied at the highest level did not depress the grain or straw yields of the cereals.

Manganese sulphate (28 and 56 lb. per acre) and ferrous sulphate (28 and 56 lb.) were found to exert no effect on the yields either in the presence or absence of applied copper. Sulphate of potash (112 lb.) was found to have no effect on

yields in the absence of copper sulphate, or where copper was applied at 28 lb. per acre, but at the 56 lb. level of copper sulphate it gave a significant increase in the yield of oats (grain only). Superphosphate applied at 112 lb. per acre did not affect the yields, but brought about a significant depression in the yield of oats (grain) at the 2 cwt. level. Neither sulphate of ammonia nor nitrate of soda, applied at 112 lb. per acre at seeding in the autumn, had any effect on the yield.

Census studies on the field experiments indicated that the increase in the yield of wheat with copper application was due to the production of a greater number of heads per plant and grains per head, and also to an increase in the average weight of individual grains. With oats the number of panicles per plant and the number of grains per panicle were greater in those plants which had been dressed with copper sulphate. The excessive tillering, which is a characteristic of copper-deficient oats, was overcome by copper dressings. In both cereals an increase in the percentage of head- or panicle-bearing tillers, and in the grain/straw ratio, was observed to follow the treatment.

Field pasture trials are in progress, and very promising results have been obtained with black medic (*Medicago lupulina*), lucerne, perennial and Wimmera rye-grass, cocksfoot, *Phalaris tuberosa,* and Yorkshire fog, sown with 28 lb. copper sulphate per acre.

(3) *Water Culture Experiments.*

The effect of minute traces of certain elements on plant growth is being investigated by means of water cultures. The extensions to one of the glasshouses have made this possible, and a technique has been developed for dealing with the very small concentrations involved. All water is redistilled from glass or silica, and all reagents are prepared to a high standard of purity.

During 1938 it was found that if traces of zinc are withheld from Algerian oats specific lesions are developed on the tips of the leaves when the plants are about the three-leaf stage of growth. These lesions appear as grey necrotic areas commencing at the tip of the leaf and extending along the margins towards the base. They eventually lead to the complete death of the leaf and plant. Zinc in concentrations as low as 20 to 50 micrograms per litre is sufficient to prevent these symptoms and supply the plants' normal requirements. The investigations are being continued to determine the symptoms of zinc deficiency in other plants.

Oats grown in solutions from which all traces of copper were removed developed the same symptoms as those noted for plants growing on Robe soil. The addition of extremely small amounts of copper enabled normal growth to be made. Slightly higher concentrations produce toxic effects and depress growth. The smallest concentration of copper necessary for healthy growth is now being determined. The effect of molybdenum and various other elements on plant growth is also being investigated.

3. THE CHEMISTRY OF PASTURES.

The intensive development of permanent pastures throughout Southern Australia is the result of their demonstrated superiority in yield, ease of control, longer growth period, and higher nutritive value throughout the year. A considerable amount of work, therefore, has been directed to the study of the seasonal differences in their chemical composition and of the factors, natural and artificially imposed, which contribute to these differences.

But there are vast areas which do not lend themselves easily to the development of seeded pastures, and the problem must be met in other ways. In 1937 an experiment was begun in collaboration with the Research Department of the Australian Estates Company Ltd. on the sheep station "Elderslie", near Winton, Queensland. The experiment was designed to obtain some knowledge of the seasonal yield and composition of a Mitchell grass pasture typical of the pastoral belt of Western Queensland. Chemical analyses of samples taken at 28-day intervals throughout the year demonstrated the existence of wide extremes in nutritive value.

The subtropical climate with the summer incidence of rainfall typical of this area resulted in active growth from January to April, but thereafter growth practically ceased, and a progressive deterioration in nutritive value set in. Phosphorus and protein, whilst adequate for nutrition during April, had reached very low values by September, and the evidence suggested that the fodder was definitely below the maintenance requirements of sheep from June onwards. Were it economically possible to harvest the whole of the April production, this would maintain in thriving condition two sheep per acre for twelve months. But the deterioration of standing grass was shown to be so great that some form of supplementary feeding was necessary for ewes and weaners, whilst drought feeding was essential if the present high mortality rate were to be materially reduced.

The lead given by these experiments has been followed up by the Australian Estates Company's Research Department, which has carried out a series of trials of supplementary and drought feeding with very interesting results.

Work has been carried out in pot cultures in connection with the associated growth of Wimmera rye-grass and subterranean clover under varying conditions of phosphorus and nitrogen supply. With increasing nitrogen dressings the contents of nitrogen in grass and clover were increased when grown alone, but when grown together the nitrogen content of the mixture was decreased owing to the suppression of the clover. Increasing the supply of phosphorus raised the phosphorus content of the grass and legume when grown either alone or in association. Its effect on the nitrogen content, however, was to raise that of the clover and lower that of the grass. The nitrogen content of the mixture was increased by phosphorus at low levels of nitrogen supply owing to clover dominance, but decreased at high levels of nitrogen supply owing to grass dominance.

In these experiments no evidence was obtained of any ability on the part of the legumes to supply the nitrogen requirements of associated non-legumes over the same growth period.

An experiment designed further to investigate this possibility of the excretion of nitrogenous compounds by the roots or nodules of lucerne by systematic leachings of a sand culture in which it was grown, gave no evidence of the possibility of such a means of transfer of nitrogen from legumes to non-legumes.

On the field side, work has been largely directed to the effects of pasture management on the chemical composition and nutritive value of a pasture consisting predominantly of *Phalaris tuberosa* and subterranean clover. The great importance of grazing management in pasture husbandry has been shown not only in the yields of herbage under the various treatments, but in their chemical composition. Stocking rates of 2, 4, and 6 sheep per acre per annum were associated with grazing rotations involving one week's grazing in every 3 weeks, one in every 6 weeks, and one in every 9 weeks. Samples taken in September, 1938, were hand-separated into four botanical groups, of which only the two important ones have as yet been chemically analysed to determine their contents of protein. The results are indicated below:

Crude Protein Content (Per Cent.—Oven Dry Basis) of Phalaris Tuberosa + Subterranean Clover Pasture.

Samples Derived from Four of the Nine Systems of Grazing Management, September, 1938.

Interval between grazings (wks.).	2 Sheep per Acre.			6 Sheep per Acre.		
	Composite herbage.	Phalaris.	Clover.	Composite herbage.	Phalaris.	Clover.
3	17·8	15·3	20·2	17·6	16·0	19·7
9	14·6	11·7	21·0	16·4	13·8	23·6

It will be observed that the length of the interval between grazings has a pronounced effect on the composition of the herbage. The effect of increasing the rate of stocking is very noticeable under the 9-weekly grazing system, the difference between the 3- and 9-weekly rotations being quite small when a stocking rate of 6 sheep per acre is employed. This being so it becomes possible to take advantage of the greater yield obtained under the longer period of rotation which had produced up till September, in addition to what the sheep had eaten, 3,100 lb. per acre as compared with 2,600 lb. per acre for the 3-weekly rotation.

While a chemical analysis provides accurate information concerning the composition of the plant, it provides no information as to the amounts of the constituents which can be utilized by the sheep. To obtain this additional information digestibility trials have been carried out, attention being directed in the first instance to hays produced under the nine systems of grazing management referred

to above. The experiment was so designed as to permit statistical treatment of the results so that errors due to sheep variability could be eliminated. Each of nine diets of meadow hay was tested on four separate sheep with the following results:

Digestible Crude Protein in lb. per 100 lb. Hay (Oven-dry Basis).

Hays Produced from Pastures Under the Nine Systems of Management.

Interval between grazings (wks.).	Stocking rate (Sheep per acre). 2	4	6
3	4·6	5·9	7·3
6	5·2	5·7	6·9
9	4·6	5·9	7·4

It is evident that with a stocking rate of two sheep per acre during the growing season the pasture made comparatively unrestricted growth, and when finally allowed to grow to the hay stage material of uniformly low digestibility was obtained, irrespective of the interval between grazings. With an increase in the stocking rate, however, a considerable improvement in the quality of the hay is to be observed. With six sheep per acre the hay from the 3-weekly system was easily the best, and even under the 9-weekly system of management it was better than that produced under stocking rates of two or four sheep per acre.

Similar results were obtained with the crude fibre. The amount of digestible crude fibre was almost exactly 20 per cent. in all cases, but was accompanied by varying proportions of indigestible crude fibre as shown:

Non-digestible Crude Fibre in lb. per 100 lb. Hay (Oven-dry Basis).

Interval between grazings (wks.).	Stocking rate (Sheep per acre). 2	4	6
3	13·2	10·7	9·1
6	12·4	10·7	9·7
9	9·1	10·7	10·6

So that again the heavier rates of stocking give rise to the best quality hays.

Attention is now being turned to the composition and digestibility of similar pasture throughout the growing season. This experiment has been designed to provide at 4- and 8-weekly intervals a continuous supply (for the period of the digestibility trial) of material which is exactly four or eight weeks old.

4. THE CHEMISTRY OF PLANT VIRUSES.

Among the diseases of plants those caused by viruses form an economically important group, and it was this circumstance which first directed attention to them. The need for investigational work on viruses and the diseases caused by them is rendered more imperative because of the circumstance that, whereas we have a fair knowledge of the nature and properties of fungi and bacteria, when work was begun on viruses at this Institute very little was known about the nature

of the causal agents of viral diseases. Since such knowledge is a necessary prerequisite for the intelligent planning of attempts to evolve control measures, the main object of the work has been to fill in this gap in our knowledge. As this work has progressed the knowledge obtained has been of such interest and fundamental importance that its pursuit is justified irrespective of the influence which it must have on the planning of control measures in the future. The early development and progress of this work up to the end of 1936 have been summarized in previous Reports. Work along similar lines has been going on at the same time in other countries, and as a result of the combined efforts of the past five or six years an important body of knowledge has accumulated.

During the two years under review investigation of the properties of the mesomorphic or paracrystalline fibrous aggregates of tobacco mosaic virus protein, described in the previous Report, was continued. A special study was made of the influence of various salts in various concentrations on the form of the virus. The critical concentration for the precipitation of virus at a strength comparable with that in the juice expressed from diseased plants has been determined for a number of salts. The virus was found to behave like a typical colloidal solution of negatively charged protein particles. The precipitating power of cations was greater the higher the valency. The effect of anions on the precipitating power was so marked that they could readily be placed in a series which was found to agree very well in principle with the Hofmeister or lyotropic series as established for other colloids. The metal ions of higher valency form insoluble compounds with the virus, but the salts of monovalent cations such as sodium, potassium, and ammonium, in nearly every case, form either the needle paracrystals or long, flexible paracrystalline fibres, according to conditions. These are easily dispersed to sub-microscopic dimensions by simple agitation or dilution. Several notable exceptions, such as the salicylate ion, are being followed up, and will be reported on later.

The separation of more concentrated solutions of mosaic virus into two phases with different optical properties (a phenomenon first recorded from England and also observed here) has also been studied further, and the conditions governing the formation of these two phases and their relative proportions have been determined under specified conditions.

Observations on the symptomatology of the virus of tomato spotted wilt on nasturtiums and other hosts have been continued and recorded photographically in cases of interest.

The investigation of the effects of reducing and oxidizing agents on the virus of tomato spotted wilt was continued.

The fluorescent substance discovered first in tobacco plants infected by the virus of tomato spotted wilt and subsequently in healthy tobacco plants has been further investigated.

Early in 1937 the substance was obtained in the form of pure crystals (melting point 208° C.). The yield is very small, and about 10,000 plants would be required to provide one gram of the pure substance. Although some interesting properties of the substance have been investigated, the main object up to the present time has been to build up a sufficient quantity of the material so that a systematic investigation can be made.

As a preliminary to a study of the function of the substance a survey was made some years ago, and it was found that the substance had a wide distribution in nature. For similar reasons the distribution of the substance in the plant has also been investigated.

The serological work begun in 1935 in collaboration with the Veterinary Pathologist of the Stock and Brands Department has been continued, in conjunction with the staff of the South Australian Institute of Medical and Veterinary Science. During the period under review the main work on this phase has been a study of the effect of electrolyte concentration on the precipitin reaction between virus antigen and antibody.

Parallel with the experiments conducted in the laboratory and in the glasshouses, small field plots of tomatoes and tobacco are maintained to supply material for observation and investigation, and for the testing of possible treatments. The spraying of tomato plants with solutions of salts of copper and zinc (selected on account of their possible effect on the oxidizing enzymes of the plant), and of potassium permanganate, sodium manganate, potassium chromate, and ferric chloride has not proved of any promise. Plants sprayed with copper salts appeared to be healthier earlier in the season, and to give a better early crop, but the effects were not great enough to justify further experiment in this direction.

A variety of tomato known as "White Beauty" was found to have approximately the same degree of susceptibility to spotted wilt as the commonly-grown variety "Early Dwarf Red". Tobacco plants of the varieties "White Stem Orinoco", "Kelly", and "Blue Pryor" grown at the Waite Institute have been found to become naturally affected by spotted wilt to the extent of 80–100 per cent.

Bacteriology

Since the beginning of 1935, the subject of bacteriology has been developed at the Waite Institute in two directions: the study of the nodule organism of leguminous plants, and the study of secondary fermentations in wines.

The studies of the nodule organism of leguminous plants have been continued with particular attention to the subject of the effectiveness of strains in relation to host plant species. The clover organism (*Rhizobium trifolii*) has proved particularly interesting, since the strains isolated from red and white clover (and effective in association with those species) are ineffective with subterranean clover, while a strain effective on subterranean clover may be ineffective on other clovers. The

lucerne and pea organisms (*R. meliloti* and *R. leguminosarum*) are being studied, and within these species also strain effectiveness appears to vary with the particular species of host plant. As a result of these investigations it appears that the parasitic habit is not a fixed quality of any strain, but is influenced to a large extent by the host plant with which it enters into association. Experiments to test how much the effectiveness of appropriate strains is reduced by "parasitic" or inappropriate strains, when both are inoculated to the same host plant, are in progress.

These strain investigations are an essential preliminary to the sound development of the practice of seed inoculation. Strains effective for particular host plants of economic importance are being made available to the State Departments of Agriculture for "bulk" distribution. The requirements of farmers and pastoralists of this State are being met by the Waite Institute, and a close interest is being maintained in the development of seed inoculation for the large-scale plantings of crop and pasture legumes in poor country of virgin character in this State. The possibilities of inoculation methods better adapted to the extensive developmental conditions in Australia are being considered.

A close contact with farmers endeavouring to convert the poor scrub lands of Kangaroo Island to productive pastures has been maintained. The application of the practice of seed inoculation alone has been insufficient to overcome the difficulties, both practical and technical in character, which have been experienced in the past. The influence of factors such as cultivation, fertilizers, and planting methods upon the effectiveness of inoculation and successful legume establishment is being studied.

A close interest in the problem of associate growth of legume and non-legume has been maintained. Although no evidence of early donation of nitrogen by the legume had been obtained in any experiments previously conducted at the Waite Institute under natural growing conditions with climatically adapted species, some evidence of such donation was obtained when the legume was subjected to conditions of shading after a period of vigorous nitrogen fixation.

Investigations on behalf of the Australian Wine Board have been continued since 1937. The organism responsible for disease in Australian fortified wines has been further studied. Its development has been found to bear a close relationship to the presence of accessory growth factors. These factors appear to be liberated during the autolysis of yeast cells in the lees, and amounts present can be varied by controlling the conditions of manufacture. The effect of tannins on the development of the bacteria is being studied.

The possibility of improving the quality of Australian sherry wine has been investigated during the past twelve months. This work is centred around the activity of a film-forming yeast, *Saccharomyces cheresiensis* Frowlow-Bagreew, which in its film stage produces the characteristic "bouquet" and taste of Spanish "fino" sherries. The conditions favouring maximum growth of the film are being studied.

Climatology

In the study of the geographical distribution of plants, animals, and soils, and in the determination of general agricultural and pastoral policies, a knowledge of climatic conditions is of fundamental importance. The factors which are of greatest significance are the amount, distribution, and reliability of the rainfall, and the temperature and humidity. These two latter together determine the rate of evaporation, which is the most important factor determining the efficiency of the rainfall and the water requirements of plants.

In connection with the work of the Institute in the semi-arid pastoral regions an examination is being made of the rainfall records of pastoral stations with the view to determining the characteristics of the distribution of the rainfall, leading to a measure of the "expectation" in a period of years of any given amount of annual or seasonal rainfall.

Two examples of agroclimatological studies have been published in the period under review, relating to the control of agriculture in South Australia, and of possible agriculture in tropical Australia. In both cases there are characteristic seasons of rainfall and of drought, and the choice of crops and of pasture species is determined by the length of these two periods. In South Australia, for example, a minimum annual period of influential rain of five months is necessary for economic wheat cultivation; subterranean clover is limited by a corresponding period of seven-and-a-half months, while a minimum wet period of nine months is required for white clover and for the standard European pasture mixtures.

The criteria which have been used in these studies are the ratios of rainfall to evaporation from a free water surface, or of rainfall to saturation deficit. It has been found desirable to use monthly values for this purpose. The period of growth for agricultural plants may be determined by the period during which the monthly rainfall exceeds one-third of the monthly evaporation. This may be referred to as the period of "influential rain".

The study of such indices in agroclimatology and bioclimatology is being continued, and is being extended to include the agricultural areas of southern Australia.

Waite Arboretum

Under the deed of gift of the late Mr. Peter Waite it was provided that portion of the area containing 67 acres should be held in perpetuity as a park, provided that a portion, not exceeding 15 acres, might be set apart for the purposes of a sports ground for graduates and undergraduates of the University. Effect has been given to both of these provisions. It was decided that the best means of carrying out the terms of the gift would be the establishment of an arboretum in which trees should be grown as specimen trees to demonstrate their value for shelter or ornamental purposes and their adaptability to the local soil and climate.

The original natural vegetation was in itself park-like, being an open savannah woodland of *Eucalyptus odorata,* and this gave promise of success in the establishment of such an arboretum.

Owing to the long, dry summer characteristic of the Adelaide environment, trees to be successful must be capable of enduring drought for some five months of the year. In the early years, however, provision has been made for the watering of all the trees. The practically complete absence of frost in the site chosen for the arboretum has probably extended the range of species likely to be found suitable. This applies more particularly to the drought-resisting tropical trees from the monsoonal regions.

Considerable interest has been shown in the development of the arboretum by district and municipal councils, particularly with respect to the choice of trees suitable for street planting. Of these the most promising have proved to be *Ficus Hillii, Vitex lucens, Tristanea conferta, Flindersia australis,* and *Bauhinia purpurea.*

In all 1,001 trees have been planted, comprising 385 species. Most of the trees were planted in the period 1928–30, but additions and replacements are being made yearly.

Papers Published by the Staff of the Waite Agricultural Research Institute 1937-1938

I. SOIL CLASSIFICATION AND SOIL SURVEYS.

J. K. Taylor. Jour. Aust. Inst. Agric. Sci. *2*: 171. 1936. (Reprint 180.)

"The Use of Moisture Equivalent as an Index of Texture for Soil Survey Purposes."

An attempt was made to correlate the moisture equivalent of soils with their clay percentage, using samples obtained during the soil survey of the Murrumbidgee Irrigation Area. For surface soils a close relation was found, and this was expressed as

$$\text{Clay} = 1{\cdot}88 \text{ M.E.} - 4.$$

For "subsoils" and "deep subsoils" other regression coefficients were obtained, but the relation in these cases was not so satisfactory owing to greater variability in exchangeable sodium.

J. A. Prescott. Rept. Aust. & New Zld. Ass. Adv. Sci. *23*: 258. 1937. (Reprint 233.)

"The Classification and Mapping of Soils." (Presidential Address to Section K of the Australian and New Zealand Association for the Advancement of Science. Auckland, 1937.)

The principles underlying the modern system of soil classification are discussed. Physical features capable of examination in the field include texture, colour, and structure. These may subsequently be given more or less precise quantitative definition in the laboratory. The ultimate system of classification is based on the whole soil profile with its sequence of horizons. Such a system lends itself both to detailed soil surveys and to regional groupings.

The progress of soil surveys in Australia and New Zealand is reviewed, and particular mention is made of surveys in the Callide Valley of Queensland, in the forests and in the wheat belt of Western Australia, and in the irrigated areas of eastern Australia.

C. G. Stephens. C.S.I.R. Bull. 108. 1937. (Reprint 200.)

"The Basaltic Soils of Northern Tasmania."

The investigation was composed of two parts:

(1) A general survey and classification of the basaltic soils, with a map showing their approximate distribution.

(2) A detailed soil survey, with a map showing the soils of part of the Burnie district.

The latter survey is intended as a basis for field experimental work by the Department of Agriculture of Tasmania on the lime requirement of these soils, and to that end a detailed study of the reaction and buffer capacity of the different soil types was made.

Attention is directed to the generally poor response of these soils to superphosphate, and it is shown that they have a high reverting power. Suggestions for special field experiments are made.

C. S. Piper and P. M. Rountree. B.A.N.Z. Antarctic Res. Expedn. 1929–31. Reports Series A. (Reprint 214.)

"1. An Examination of Soils from Possession, Heard, Kerguelen, and Macquarie Islands.

"2. Bacterial Examination of Soils from Macquarie Island."

1. Seventeen soils from subantarctic islands, collected by Sir Douglas Mawson during the 1929–31 B.A.N.Z.A.R. Expedition have been examined and described. The samples are mostly surface soils, only one complete profile being included. Low temperatures have favoured an accumulation of organic matter, and the soils are peaty in nature, containing up to 60 per cent. organic matter. The reaction varies from pH 3·8 to 5·4. Buffer capacity and exchangeable bases are also given. Chlorides, probably derived from the close proximity of the soils to the sea, are unduly high in some samples. The soils are considered to be of a *moor* or *tundra* type.

2. Bacterial counts have been made on four of the Macquarie Island soils, and the presence of various protozoa, azotobacter, and a nitrifying bacillus has been qualitatively demonstrated.

R. L. Crocker and B. E. Butler. Jour. C.S.I.R. *11*: 143. 1938. (Reprint 221.)

"A Soil Survey of the Horticultural Portion of the Mypolonga Irrigation Area (South Australia)."

Part of the area of 1,250 acres covered in this soil survey was under consideration as an extension of the present settlement at Mypolonga. It was concluded that soils with more than 24 inches of surface sand overlying the stony or hardpan layer, commonly found in the major types, are suited to horticultural purposes. The problems of high water table and salt accumulation are briefly discussed. One new soil type is named and described.

C. S. Piper. Trans. Roy. Soc. Sth. Aust. *62*: 53. 1938. (Reprint 228.)

"The Red-Brown Earths of South Australia."

The red-brown earths of South Australia are developed principally on the western slopes of the Mount Lofty Ranges and on the central highlands of the middle north. They occur as a longitudinal belt extending for about 150 miles north of Adelaide, and include the most productive wheat-growing soils of the State. The soils are typically brown sandy loams, slightly acid in reaction in the surface horizons, and becoming heavier and redder with depth. Calcium carbonate always occurs below the zone of clay accumulation. The climate and vegetation of the area are briefly discussed, and it is considered that the soils have certain affinities as a group with the Mediterranean red earths (terra rossa).

The mean values for the proportions of exchangeable Ca, Mg, K, and Na are 61 : 24 : 11 : 4 in the surface soils, 62 : 33 : 8 : 7 in the intermediate horizons, and 44 : 41 : 6 : 9 in the subsoils. There is a significantly lower proportion of exchangeable Na in the red-brown earth subsoils than in the subsoils of the South Australian mallee. The mean value for the base exchange capacity of the clay fraction is 0·48 milligram equivalents per gramme of organic C. An appendix gives the locality and description of 36 profiles, and includes detailed mechanical and chemical analyses of 200 individual soil samples.

The Waite Institute profile, which belongs to this group of soils, is described elsewhere in this Report (page 94).

J. A. Prescott. Jour. C.S.I.R. *11*: 261. 1938. (Reprint 238.)

"Some Characteristics of Soils Used for the Cultivation of Peanuts (*Arachis*) in the Northern Territory of Australia."

Soils from Daly River and Katherine in the Northern Territory have been collected and subsequently examined in the laboratory. The soils are alluvials from the immediate banks of the river; they are brown in colour and light-textured. Soils considered particularly suitable for the cultivation of peanuts show characteristic mechanical analyses with 5–7 per cent. of clay and 60–70 per cent. of fine sand with very little silt. Relatively low values for phosphate suggest that phosphatic fertilizers may be of some value.

J. A. Prescott and H. R. Skewes. Trans. Roy. Soc. Sth. Aust. *62*: 320. 1938. (Reprint 242.)

"An Examination of Some Soils from the More Arid Regions of Australia."

The opportunity has been taken of securing a reference collection of soils from the more inaccessible regions of Australia through the help of various expeditions. Fifty localities are represented, with several sites in

some localities. The north-eastern pastoral soils of South Australia are included.

Mechanical analyses are discussed under three main groups; the desert soils, the pastoral district above-mentioned, and the desert sandhills. The modal frequency of particle size in the desert sands lies about the conventional dividing-line between coarse sand and fine sand, namely 0·2 mm. In reaction, expressed as pH values, the north-eastern pastoral soils are alkaline, the soils associated with the central ranges are neutral to alkaline, and those associated with the Granites country and Gibson's Desert, are neutral to acid.

Soluble salts are not abundant except in special cases. Analyses for the main plant nutrients suggest that phosphate determines the level of fertility, and this is reflected in the character of the native vegetation. In a range of P_2O_5 from 0·006 per cent. to 0·098 per cent. the vegetation associations progress from porcupine grass, through mulga to bluebush, and finally to saltbush. Twelve profiles are selected for detailed examination. An important feature is the presence of a super surface (A_0) horizon where the vegetation has not been destroyed.

J. S. Hosking. Trans. Roy. Soc. Sth. Aust. *62*: 366. 1938. (Reprint 246.)

"Some Recent Volcanic Deposits and Volcanic Soils from the Island of New Britain in the Territory of New Guinea."

A suite of volcanic deposits resulting from the recent eruptions at Rabaul, the capital of the Territory of New Guinea, together with a series of soils developed upon similar parent materials, from the Island of New Britain, has been examined.

All the samples examined fall within a characteristic grouping with respect to the mechanical composition of the mineral fraction.

While the recent deposits may contain up to 5 per cent. of soluble salts, the soils, despite their possible proximity to continuous solfataric or fumarole activity are particularly free from salt owing to the intense leaching effects prevailing under the heavy rainfall conditions.

The deposits and soils vary from slightly acid to neutral in reaction, and the latter are notable for their natural fertility.

II. AGRICULTURAL CHEMISTRY—LABORATORY TECHNIQUE.

R. E. Shapter. Aust. Chem. Inst. Jour. & Proc. *4*: 413. 1937. (Reprint 206.)

"The Estimation of Phosphoric Acid in Plant Material."

The effects of precipitating ammonium phosphomolybdate under varying conditions have been examined and a method of wet oxidation of plant material by means of nitric and perchloric acids has been described.

In the case of the Pemberton-Neumann method as described by Richards and Godden for faeces, etc., in order to ensure complete precipitation it was found necessary to add more nitric acid than they specify. Under these conditions a lower factor than that found by Richards and Godden was obtained. Provided that CO_2 was excluded, the Pemberton-Neumann procedure offered no special advantages over the more rapid Pemberton procedure. Under varying conditions of precipitation variations in the factors for P_2O_5 were found.

Wet oxidation by nitric-perchloric acids is decidedly more rapid than the nitric-sulphuric method, and the factor remains constant over a wider range of P_2O_5 content.

Increasing the amount of ash constituents relative to P_2O_5 content in general resulted in lower factors being obtained; the factor should be determined as nearly as possible under the exact conditions obtaining in the actual analytical procedure.

The gravimetric Lorenz method of determining P_2O_5 following nitric-perchloric oxidation has shown promise of giving accurate results with smaller amounts of P_2O_5 than volumetric Pemberton procedures.

C. S. Piper. Aust. Chem. Inst. Jour. & Proc. *5*: 312. 1938. (Reprint 229.)

"The Use of Selenium as a Catalyst in the Kjeldahl Method for estimating Nitrogen."

A comparison has been made of the relative values of selenium and copper as catalysts in the Kjeldahl method. Selenium was found to be more active than copper in promoting the destruction of organic matter and its use reduced the time required to obtain a clear digest by twenty to thirty minutes. When using selenium the amounts of nitrogen found were equal to or slightly greater than those obtained in the presence of copper sulphate. Under the conditions of digestion used there was no evidence of a loss of nitrogen when excessive amounts of selenium were present.

A. Walkley. Aust. Chem. Inst. Jour. & Proc. *5*: 291. 1938. (Reprint 230.)

"The Polarographic Method as Applied to the Chemical Analysis of Metals."

A general account of the principles and experimental technique of the polarographic method of analysis has been given, followed by a discussion of its advantages and limitations.

The method, which owes its development almost exclusively to the work of Heyrovsky and his colleagues in Prague, depends for its success on the interpretation of current-voltage curves obtained when a solution of metallic salts is polarized under a gradually increasing E.M.F., at a dropping mercury cathode. It is very sensitive, metals in concentrations of from 10^{-5}

to 10^{-6} gram-equivalents per litre being detectable, while simultaneous determinations of several metals are frequently possible with an accuracy of $\pm$ 5 per cent.

J. S. Hosking. Jour. Agric. Sci. *28*: 393. 1938. (Reprint 232.)

"The Ignition at Low Temperatures of the Organic Matter in Soils."

The ignition of soil organic matter at temperatures ranging from 100° to 500° C. has been investigated. Appreciable losses are found to occur below 100° C.; up to 200° C. heating results in the distillation of volatile constituents, while up to 300° C. destructive distillation is the major reaction. These reactions are responsible for the removal of 85 per cent. of the organic matter.

Two hours' heating of the soil at 450° C. or half-an-hour's at 500° C. are recommended for the removal of 99 per cent. of the soil organic matter.

A. C. Oertel. Jour. Aust. Inst. Agric. Sci. *4*: 141. 1938. (Reprint 244.)

"The Spectrograph in Relation to Agricultural Problems."

Some problems encountered in agricultural research in connection with which the spectrograph offers material scope are mentioned. A simplified account of the methods of spectrographic analysis, qualitative and quantitative, is given, the account being restricted to methods applicable to agricultural samples.

A few agricultural research problems for the solution of which the spectrographic method should prove valuable are discussed, and some of the difficulties encountered are noted.

III. MINERAL DEFICIENCIES.

C. M. Donald, C. S. Piper, and D. S. Riceman. Jour. Aust. Inst. Agric. Sci. *4*: 41. 1938. (Reprint 216.)

"Response to Copper on a South Australian Soil."

A copper deficiency of plants has been found to occur at Robe on a soil derived from wind-blown calcareous sand. The symptoms in cereals were identical with those described for "reclamation disease" (*Urbarmachungskrankheit*) of northern Europe and the application of copper sulphate has led to normal growth. Copper sulphate also increased the growth of subterranean clover in pots, but 28 lb. per acre was not sufficient to secure good pasture establishment in the field.

D. S. Riceman, C. M. Donald, and C. S. Piper. C.S.I.R. Pamph. 78. 1938. (Reprint 224.)

"A Copper Deficiency in Plants at Robe, South Australia.

"1. Preliminary Investigations on the Effect of Copper and Other Elements on the Growth of Plants in a 'Coasty' Calcareous Sand at Robe, S.A.

"2. The Occurrence of 'Reclamation Disease' in Cereals in South Australia."

The natural pastures of the blown calcareous sands of coastal South-East of South Australia are composed of inferior annual grasses, and attempts to establish superior pasture species suited to the climate have failed. Of the cereal crops only rye can be successfully grown. Oats, wheat, and barley grown on this soil suffer from a disease which has been shown to be due to copper deficiency, and which corresponds with "reclamation disease" of northern Europe. The leaves of the plants droop, and there is considerable withering and death of the leaf tips. The base of the plant tends to remain green, and fresh tillers are continually produced. Should the heading stage be reached grain is rarely formed. The disease can be controlled by the application of copper sulphate.

Pasture species respond to copper less readily than do the cereals, but it is likely that the use of copper sulphate will extend the range of successful species.

J. A. Prescott. Science Review 8. 1938. (Reprint 234.)

"Soil Deficiencies." Sixth T. S. Hall Memorial Lecture of the Melbourne University Science Club.

A review of recent work in Australia and New Zealand on deficiencies in the soil as revealed by low yields, by low carrying capacities for stock, and by plant and animal diseases. The mutual relationships of phosphorus and nitrogen deficiencies are indicated, and the recent discoveries of the importance of zinc, boron, copper, manganese, and cobalt are discussed.

IV. FIELD CROPS, PASTURES, AND WEEDS.

H. C. Trumble. Scott. Geog. Mag. *53*: 10. 1937. (Reprint 183.)

"The Development of Pastures in South Australia."

A brief account of agricultural and pastoral development in South Australia, with particular reference to vegetation regions and factors influencing pasture development, such as the use of superphosphate and the exploitation of improved pasture species.

T. H. Strong. Jour. C.S.I.R. *10*: 12. 1936. (Reprint 187.)

"The Influence of Host Plant Species in Relation to the Effectiveness of the Rhizobium of Clovers."

A strain of symbiotic bacteria effective with one host plant species may not be effective with all species of the cross-inoculation group. Strains of the clover nodule-producing organism isolated from subterranean clover

have proved effective in association with that plant, and ineffective with red and white clover, and vice versa. The same strains freely infect the roots of all three clover species, but a distinct type of ineffective nodulation is produced upon the unsuitable host plant.

H. C. Trumble. Jour. Agric. Sth. Aust. *40*: 779. 1937. (Reprint 192.)

"Some Factors Affecting the Germination and Growth of Herbage Plants in South Australia."

The minimum, optimum, and maximum temperatures for germination were determined for typical legumes, summer grasses, cultivated winter grasses, non-cultivated grasses, and miscellaneous species.

The early development of the grasses and pasture legumes from seed in South Australia is discussed in relation to the range of temperatures for germination, seed permeability, the early commencement of seasonal rains, superphosphate application, and the factor of competition.

H. C. Trumble, T. H. Strong, and R. E. Shapter. C.S.I.R. Bull. 105. 1937. (Reprint 198.)

"Investigations on the Associated Growth of Herbage Plants.

"1. On the Nitrogen Accretion of Pasture Grasses when Grown in Association with Legumes.

"2. The Influence of Nitrogen and Phosphorus Treatment on the Yield and Chemical Composition of Wimmera Rye-grass and Subterranean Clover, Grown Separately and in Association.

"3. The Yield and Nitrogen Content of a Perennial Grass (*Phalaris tuberosa*) when Grown in Association with Annual Legumes."

1. Pot experiments were carried out in which rye-grass and *Phalaris* were grown in association with lucerne or subterranean clover or with both. No evidence was obtained during the winter that the grasses were able to secure nitrogen from the associated legumes during the vegetative stages of the latter. Nitrogen became available, however, during senescence.

In cultures grown in spring and early summer some evidence of a transfer of nitrogen was obtained from twelve weeks after seeding, but not to the extent suggested by other workers.

2. Wimmera rye-grass and subterranean clover were grown singly and in association under varying conditions of phosphorus and nitrogen supply in sand cultures. The plants were sampled for the determination of dry weight and content of nitrogen and phosphoric acid. There was no evidence in any treatment that the grass grown with clover was higher in dry matter or in total nitrogen than the grass grown alone. In most cases the dry matter and nitrogen accretion were lower in the grass grown in association with clover.

The main practical conclusion is that under soil conditions where both the nitrogen and phosphate levels are low, the most efficient building-up of fertility is likely to be obtained by the use of suitably inoculated legumes and by liberal dressings of soluble phosphate. As nitrogen enrichment proceeds grasses will become more prominent.

3. At the completion of the growth of an annual legume, nitrogen becomes available in the root medium, and a perennial grass, capable of maintaining its vegetative development for an extended period, may derive material quantities of nitrogen therefrom.

With *Medicago denticulata* as the associate legume, *Phalaris tuberosa* was able to obtain approximately 30 per cent. of the nitrogen present in the root system and gained by the culture medium, under favourable conditions of moisture supply, in a period of eight weeks following the harvest of the legume.

Nitrogen enrichment is greatest in the case of pure legumes. The presence of associate grasses will tend to reduce the amount of nitrogen gained as the proportion of grass is increased.

C. M. Donald and C. A. N. Smith. Jour. C.S.I.R. *10*: 277. 1937. (Reprint 208.)

"Strain Variation in Subterranean Clover (*Trifolium subterraneum* L.)."

Fourteen strains of subterranean clover were studied in the field. The yield of dry matter, percentage of leaf, and number of flowers per plant were each shown to be positively and strongly correlated with lateness of maturity. The climatic conditions during the flowering period (as measured by evaporation from a free water surface) control the effectiveness of the seed-setting.

The interaction of the number of flowers formed and the percentage flower abortion in controlling the quantity of seed produced by strains of different maturity under varying climatic conditions is considered.

T. H. Strong. Jour. Agric. Sth. Aust. *41*: 542. 1937. (Reprint 211.)

"Legume Establishment and its Function in Relation to the Development of Some of the Poor Soils on Kangaroo Island."

Many difficulties of technical and practical order must be overcome before poor soils carrying stunted sclerophyllous scrub and heath can be economically developed to pastures. The methods which have proved successful in the development of soils of better class for cereal production have proved to be failures upon these "ironstone" types of soils of low initial fertility. A programme of effective cultivation in conjunction with the use of suitable "pioneer" legumes is suggested. Many factors which have to be considered if the rhizobium-phosphate combination is to be efficiently utilized to develop these poor soils are discussed.

J. G. Davies, A. E. Scott, and J. F. Kennedy. Jour. C.S.I.R. *11*: 127. 1938. (Reprint 220.)

"The Yield and Composition of a Mitchell Grass Pasture for a Period of Twelve Months."

Samples were taken at 28-day intervals throughout the year, and showed wide extremes of production and nutritive value. As a result of the summer rainfall typical of this area, growth was rapid from January to April, but thereafter ceased. Rapid deterioration in yield and nutritive value of the herbage occurred from April to September. Phosphorus and protein, whilst adequate for nutrition in April, had reached very low values by September, and the data suggest that both were inadequate for the requirements of sheep from June onwards. The low level of calcium throughout the year was associated with the dearth of legumes in the sward.

H. C. Trumble and C. M. Donald. C.S.I.R. Bull. 116. 1938. (Reprint 222.)

"The Relation of Phosphate to the Development of Seeded Pasture on a Podsolized Sand."

A detailed study was made of the relationship of clover and grass development to phosphate application on a virgin podsol at Meadows, South Australia.

In each of the three seasons the dry matter production of the clover bore a Mitscherlich relationship to the phosphate application. Phosphate recovery tended to be directly proportional to the effective phosphate dressing within the range employed. These two relationships were so strong as to permit accurate determination of the residual effect of previously applied phosphate.

A perennial associate grass (*Phalaris tuberosa*) was successfully included in the original seeding, despite the initially low phosphate and nitrogen content of the soil, and the development of the grass rose markedly as the phosphatic dressing was increased.

It was shown that early in the season nitrogen accumulated previously was of great importance in determining the development of associate grasses, but that later in the season phosphate assumed a major rôle.

It is suggested that dressings of at least 2 cwt. per acre of superphosphate be applied annually for the first three years to newly-established stands of subterranean clover on this or similar soil types. The question of incorporation of associate grasses is discussed.

H. C. Trumble. Jour. Aust. Inst. Agric. Sci. *4*: 66. 1938. (Reprint 223.)

"Some Introductory Principles of Pasture Ecology."

A discussion on recent developments in the study of pastures, on the difference between the pasture complex and the single agricultural crop

unit, and on the effects of the climatic, edaphic, and biotic factors as they affect pastures. The ecological aspect of pastures is emphasized.

H. C. Trumble, C. M. Donald, and C. A. N. Smith. C.S.I.R. Bull 122. 1938. (Reprint 247.)

"The Establishment of Pastures on Deep Sands in the Upper South-East of South Australia.

"1. The Origin and Scope of the Investigations.

"2. The Influence of Cover Crops and Fertilizer Treatment on the Establishment of Selected Herbage Species."

With an Appendix on the Rôle of Seed Inoculation, T. H. Strong.

Lucerne, early-flowering subterranean clover, and Wimmera rye-grass are the most suitable species for extensive seeding in the development of the "heath" country of the Upper South-East of South Australia. This mixture can be successfully established with a lightly-sown cereal cover crop. Annual dressings of 1½ cwt. per acre of superphosphate are more productive and profitable than lighter dressings.

The relationship between cereal and leguminous cover crops and the various pasture constituents was studied in detail.

On land cleared and grazed for a number of years lucerne, *Phalaris tuberosa,* and early-flowering subterranean clover will give a highly productive permanent pasture. On deep sandhill country evening primrose (*Oenothera odorata*) is a valuable species.

On newly-developed areas inoculation of lucerne seed with a suitable strain of Rhizobium is essential.

H. C. Trumble and C. M. Donald. Jour. Aust. Inst. Agric. Sci. *4*: 206. 1938. (Reprint 250.)

"Soil Factors in Relation to the Distribution of Subterranean Clover and Some Alternative Legumes."

Subterranean clover has failed as a pasture legume on soils of high lime status and alkaline reaction in South Australia. These soils are the heavy black soils of the South-East, the coastal calcareous sands, the grey soils of the "Wimmera" type, and the Mallee soils.

On each of these soil types the cultivation of *Medicago* species is proving successful. Lucerne is valuable on all such soils, while *M. lupulina* may be used in areas having a rainfall season over 7·5 months, and *M. tribuloides* in drier districts.

G. H. Clarke. Jour. Aust. Inst. Agric. Sci. *3*: 206. 1937. (Reprint 210.)

"Noxious Weed Investigations Considered as a Negative Phase of Agricultural Research."

A discussion of noxious weed investigation in relation to other branches of agricultural research and the contribution of the agronomist, chemist, entomologist, and botanist. The various divisions of agricultural research are considered from the two points of view of growth promotion, as applied to favoured herbage, and its negative phase, plant repression.

The economic difficulties to be faced are those of varying land use and value, which make a special case of every weed occurrence. The botanist's share of the work is an intensive initial study of the plant itself.

G. H. Clarke. Jour. Agric. Sth. Aust. *40*: 956. 1937. (Reprint 212.)

"Important Weeds of South Australia—Horehound (*Marrubium vulgare* L.)."

This is a perennial plant introduced from Europe and Asia to most of the Australian States. It is a proclaimed noxious weed in South Australia, and is becoming increasingly important.

The description, classification, properties, and uses of the plant are given.

It is not a serious menace on cultivated land or sown pastures, but colonizes waste lands and poor, eroded soil readily.

Control is by cultivation or the use of sodium chlorate.

G. H. Clarke. Jour. Agric. Sth. Aust. *41*: 240. 1937. (Reprint 217.)

"Important Weeds of South Australia—False Caper (*Euphorbia terracina* L.)."

The history and distribution of this Mediterranean plant in South Australia are given; its habitat in this State is mainly on the coastal sand dunes near Adelaide, and inland to some extent.

The plant was proclaimed a noxious weed in 1903 under a mistaken name.

Botanical characters, description, and classification are set out. The milky sap is probably poisonous, and eradication by cultivation or chemical methods is possible, but often uneconomical.

C. A. N. Smith. Jour. Agric. Sth. Aust. *41*: 921. 1938. (Reprint 225.)

"A Preliminary Investigation of the Relative Effectiveness of Various Chemicals in the Control of Some Common Weeds."

While effective control of certain annual weeds such as Capeweed, wire weed, soursob, and *Myagrum perfoliatum* resulted from a single application of solutions of 5 per cent. sulphuric acid, 1¼ per cent. arsenic pentoxide, 2½ per cent. sodium chlorate, and 5 per cent. ammonium thiocyanate, higher concentrations were necessary to bring about a high mortality in certain

gramineous species, viz. wild oats, barley grass and wheat, and to a lesser extent three-cornered jack.

A single application of a 20 per cent. solution of sulphuric acid, arsenic pentoxide or sodium chlorate did not give a sufficient measure of control of couch grass or nut grass, while arsenic pentoxide was the only chemical to satisfactorily control field bindweed. Sulphuric acid proved particularly ineffective on these deep-rooted perennial weeds owing to the vigorous regeneration which followed treatment.

V. PLANT NUTRITION AND PLANT PHYSIOLOGY.

A. H. K. Petrie, A. G. Strickland, H. C. Trumble, and A. E. V. Richardson. Jour. Aust. Inst. Agric. Sci. *3*: 154. 1937. (Reprint 202.)

"Recent Advances in the Study of Plant Nutrition."

A summary of a symposium held at a meeting of the South Australian Branch of the Australian Institute of Agricultural Science.

A. H. K. Petrie. Aust. Jour. Exp. Biol. & Med. Sci. *15*: 385. 1937. (Reprint 207.)

"Physiological Ontogeny in Plants and its Relation to Nutrition.

"3. The Effect of Nitrogen Supply on the Drifting Composition of the Leaves."

This paper is a continuation of the account given in the first paper of the series of the effect of increasing over a certain range the initial nitrogen supply to wheat and Sudan grass. An account is given of the effect of nitrogen supply on the drifting absolute and percentage amounts in the leaves of protein nitrogen, soluble nitrogen, total phosphorus and water. Results are also given for the nitrogen and water contents of the third leaf in wheat. It is suggested that the initial depression in dry weight produced by high nitrogen treatment is caused by a temporary reduction in water content of the plant, leading to reduced protein content of the leaves and a temporarily reduced unit leaf rate. A synoptical account is given of the factors that determine the rates of import and export of nitrogen and phosphorus by the leaves. The relation of the water content of the leaves to their protein-nitrogen content is also discussed.

R. F. Williams. Aust. Jour. Exp. Biol. & Med. Sci. *16*: 65. 1938. (Reprint 213.)

"Physiological Ontogeny in Plants and its Relation to Nutrition.

"4. The Effect of Phosphorus Supply on the Total-, Protein-, and Soluble-Nitrogen Contents, and Water Content of the Leaves and Other Plant Parts."

This paper extends the account given in the second paper of the series of the effects of different initial supplies of phosphorus on oat plants grown

in sand culture. Up to the time of flowering the leaves of the plants with the lowest supply of phosphorus had low values for absolute protein-nitrogen and water, but the reduction in absolute soluble-nitrogen was much less marked; after flowering treatment effects were slight. The percentage amounts of protein nitrogen and water with this treatment were at first depressed below those for the higher treatments, but these relationships were soon reversed. The relative content of soluble nitrogen was from an early stage considerably increased by low phosphorus supply. The growth of the plants receiving the two higher supplies of phosphorus was probably limited by the supply of nitrogen, and this is reflected in the similarity of their absolute and relative contents of protein nitrogen, soluble nitrogen, and water in the leaves. Several factors that determine the rates of import and export of nitrogen by the leaves are discussed in relation to the data of the experiments. The withdrawal of nitrogen from the primary shoot by developing tillers is demonstrated for plants receiving the two higher levels of phosphorus supply.

A. H. K. Petrie and R. F. Williams. Aust. Jour. Exp. Biol. & Med. Sci. *16*: 347. 1938. (Reprint 245.)

"Physiological Ontogeny in Plants and its Relation to Nutrition.

"5. The Effect of Nitrogen and Phosphorus Supplies on the Respiration Rate of the Leaves."

An account is given of the drift with time in respiration rate of the total leaves in two of the experiments described in previous papers of this series. In one of these experiments Sudan grass was grown with varying nitrogen treatments, and in the other oats were grown with varying phosphorus treatments. On a dry-weight basis the respiration rate had an early maximum, after which it declined continuously with time. Increasing nitrogen treatment caused a general increase in rate. Up to a point increased phosphorus treatment caused an increase in rate during the early growing period, but this effect was subsequently reversed, just as was previously found in the case of protein-nitrogen content.

Analysis of the data leads to the conclusion that not only the decline in respiration rate with time but also treatment effects thereon are to a considerable extent the result of variations in the cytoplasm content of the leaves; it is also concluded that, in data extending over a wide ontogenetic range, the content of cytoplasm is probably roughly measured by the protein content of the leaves. There is evidence, however, that other factors, possibly including concentration of respiratory substrates, influenced the respiration rates observed.

A. H. K. Petrie and J. G. Wood. Ann. Bot. N.S. *2*: 33. 1938 (Reprint 219.)

"Studies on the Nitrogen Metabolism of Plants.

"1. The Relation between the Content of Proteins, Amino-acids, and Water in the Leaves."

This paper is an account of an investigation of the relation between the amount of protein in the leaves of grasses and certain other quantities which varied as the result of experimental treatment of the plants. The results suggest that, under environmental conditions constant in certain respects, the protein content of the leaves increases with both amino-acid content and water content, and it seems probable that this relationship also holds at the steady state. The picture suggested is that the net rate of formation of protein from amino-acids decreases with reduction in water content, although it cannot be determined whether synthesis is decreased or hydrolysis is increased, or whether both are affected. The effect of water content on the protein amino-acid relation may be merely the result of change in the concentrations of these two components of the system; change in water content may, on the contrary, affect the rate of some reaction or reactions in the sequence, or else it may be a measure of some other factor that does so. It is shown, incidentally, that increasing the supply of NH_4-ions to the roots of a plant causes, over a certain range, marked reductions in the water content of the leaves.

J. G. Wood and A. H. K. Petrie. Ann. Bot. N.S. *2*: 729. 1938. (Reprint 240.)

"Studies on the Nitrogen Metabolism of Plants.

"2. Interrelations among Soluble Nitrogen Compounds, Water and Respiration Rate."

The relations in the leaves of grasses among the contents of soluble nitrogen compounds and of water and the respiration rate were studied under constancy of certain environmental factors. The curves relating amino-nitrogen content and amide-nitrogen content to the ammonia-nitrogen content are concave to the ammonia-nitrogen content axis; no consistent effect of water content on the relationship could be found. Respiration rate rises as the water content falls to a certain level; further fall in water content causes respiration rate to fall.

A. H. K. Petrie and J. G. Wood. Ann. Bot. N.S. *2*: 887. 1938. (Reprint 251.)

"Studies on the Nitrogen Metabolism of Plants.

"3. On the Effect of Water Content on the Relationship between Proteins and Amino-acids."

This is a further consideration of the mechanism whereby water content affects the relationship between proteins and amino-acids. Further

evidence is brought forward that it may be purely a concentration phenomenon. It is also pointed out that decreasing water content could lead to protein hydrolysis if it caused a decrease in concentration of one or more amino-acids. It is shown that the amount of one amino acid, viz. cystine, does not always increase, and sometimes actually decreases, when the amount of the other amino-acids increases. In the experiment in which this was demonstrated water and amino-acid contents were negatively correlated, so that it cannot be concluded whether decreasing water content or increase in concentration of the amino-acids is the immediate cause of cessation of increase in cystine content.

VI. FUNGUS AND VIRUS DISEASES OF PLANTS.

D. B. Adam. Jour. Agric. Sth. Aust. *40*: 693. 1937. (Reprint 189.)

"Silver Leaf Diseases in Orchard Trees."

Silver leaf (*Stereum purpureum*) is increasing in the plum-growing areas situated in the hills behind Adelaide. This is a popular account of the symptoms of the disease supplemented by directions for its control.

D. B. Adam. Jour. Agric. Sth. Aust. *40*: 732. 1937. (Reprint 190.)

"Notes on Plant Diseases in South Australia During the Two-year Period to 30th June, 1936."

Attention is drawn to the first recorded occurrence of tomato leaf mould (*Cladosporium fulvum*) in South Australia.

An outbreak of streak (tomato spotted wilt virus) was observed in a bed of green garden peas immediately following tomatoes. The same virus also commonly affects cinerarias, zinnias, and Iceland poppies in suburban gardens.

The remainder of the report deals briefly with the relative incidence of the more common South Australian plant diseases during the period under review.

D. B. Adam and T. T. Colquhoun. Jour. Agric. Sth. Aust. *40*: 787. 1937. (Reprint 196.)

"Barley Diseases in South Australia and Their Control."

Leaf stripe (*Helminthosporium gramineum*) is recorded for the first time in South Australia. A six-rowed variety, known locally as Californian Cape, and used for malting purposes, is principally affected. Field experiments on the control of smut (*Ustilago hordei*) and of leaf stripe are described.

In the 1935 experiment for smut control treatment by formalin 1–320 (sprinkle) and formalin 1–400 (steep) reduced the disease from 5·8 per

cent. in the controls to 2·1 per cent. and 0·2 per cent. respectively. Copper carbonate (2 oz. per bush.) reduced the disease to 1·2 per cent., while Ceresan (U.T. 1875A) and Agrosan G eliminated it entirely. In the 1936 experiment Ceresan and Agrosan 13536 again gave complete control. Experiments in 1936 for leaf stripe control showed that Ceresan (U.T. 1875A) and Agrosan 13536 were effective, while formalin 1–320 (sprinkle) and copper carbonate only partially controlled the disease.

I. F. Phipps. Jour. Aust. Inst. Agric. Sci. *4*: 148. 1938. (Reprint 236.)

"The Effect of Leaf-Rust on Yield and Baking Quality of Wheat."

In a study of the effect of leaf rust on yield and other characteristics of wheat, in which leaf rust was controlled by spraying with colloidal sulphur, it was found that severe infection reduced the yield of a susceptible variety (Ranee) by 14·5 per cent. The greater part of this reduction in yield was due to a smaller weight of grain and a lower bushel weight. Leaf rust infection also reduced the nitrogen content of the grain and the loaf volume of experimental loaves baked from the grain.

Spraying with colloidal sulphur had no measurable effect on the yield and other attributes of a strain of wheat resistant to leaf rust.

D. B. Adam. Jour. Agric. Sth. Aust. *42*: 14. 1938. (Reprint 241.)

"A Progress Report on a Gummosis (Dieback) Disease in South Australian Apricot Trees."

This disease is of considerable economic importance in the non-irrigated apricot-growing districts of South Australia. It is most common on trees ten or more years old. The symptoms of the disease are described and illustrated. In its general features the disease usually involves the main branches one after another in a progressive dieback. Both wood and bark tissues are affected. In the wood the disease may spread several feet from its point of origin. Spread across the branch is slow. When this is nearly complete its sudden death is a feature. The disease occurs principally on apricots, but in rare cases it has been seen on peaches and plums.

The disease is caused by a fungus which is readily isolable from the diseased wood. Under favourable circumstances it forms pycnidia immersed in the bark tissues. The fungus is assigned to the form genus *Cytosporina*, but no detailed description of it is given.

Inoculation experiments using mycelium developed from pure cultures of the fungus isolated from the wood, and with suspensions of spores from pycnidia, have yielded positive results in more than 50 cases. Other experiments on the relation of type and size of wound to infection are described and the results tabulated. Wounds, especially those exposing the wood, are a necessary precedent to infection.

Experiments to test the possibility of transmitting the disease by means of pruning tools show that the pruning saw may do this. No evidence of immunity to the disease has been found among the common apricot varieties.

A short account of the principles involved in the control of this disease is given, and reference made to work in hand testing practicable measures that is being carried out by the State Department of Agriculture.

R. J. Best. Nature *139*: 628. 1937. (Reprint 188.)

"Visible Mesomorphic Fibres of Tobacco Mosaic Virus in Juice from Diseased Plants."

Samples of clarified juice from tobacco plants artificially infected with the virus of tobacco mosaic when allowed to stand deposited a fibrous mass of protein, which appeared to be identical in other properties with the virus protein itself. These fibres were doubly refractive when examined by polarized light, but their flexibility and other properties were similar to those associated with the mesomorphic or paracrystalline state. The fibres lost their infectivity as well as their structure when heated to 92° C. After describing other properties of the fibres it was concluded that the fibres consist of long chains of virus particles linked together by relatively feeble bonds.

R. J. Best. Aust. Jour. Exp. Biol. & Med. Sci. *15*: 65. 1937. (Reprint 194.)

"The Quantitative Estimation of Relative Concentrations of the Viruses of Ordinary and Yellow Tobacco Mosaics and of Tomato Spotted Wilt by the Primary Lesion Method."

As a result of dilution-infectivity tests it was shown that for ordinary and yellow tobacco mosaic viruses the dilution curves may be divided into three parts:

(a) A flat portion at high virus concentrations where a large change in concentration results in a much smaller change in the number of lesions produced.

(b) A straight line section covering a useful concentration range where a change in concentration is accompanied by an equivalent change in the number of lesions.

(c) A section at high dilutions where changes in lesion numbers are again proportionately smaller than changes in concentration.

The general shape of the curve for tomato spotted wilt virus is similar to that of tobacco mosaic except at the lower concentrations, where changes in the number of lesions are proportionately greater than changes in virus concentration.

The age and condition of test plants, the time elapsing between inocula-

tion and the lesion count, and the conditions (in respect to temperature and light) prevailing subsequent to inoculation have been shown to affect the form of the curves for one or more of these viruses.

The probable effect of the degree of aggregation of virus particles and other factors are discussed in their bearing on the form of the curve. It was shown that under controlled conditions the portion (b) of the curves provides a useful working range in which to estimate relative concentrations with a reasonable degree of accuracy.

R. J. Best. Aust. Jour. Exp. Biol. & Med. Sci. *15*: 191. 1937. (Reprint 201.)

"On the Presence of an 'Oxidase' in the Juice Expressed from Tomato Plants Infected with the Virus of Tomato Spotted Wilt."

Evidence is recorded to show that the juice expressed from the leaves of tomato plants infected with the virus of tomato spotted wilt contains an "oxidase" enzyme (tentatively identified as tyrosinase) which catalyses the oxidation of phenol, catechol, quinol, and tyrosine in the presence of air. The reaction does not proceed to a demonstrable extent in suspensions of juice expressed from comparable parts of healthy plants, but it does in suspensions of root juice.

The enzyme was also present in juice expressed from tobacco leaves infected with tomato spotted wilt, but not in the juice from similarly infected nasturtium leaves.

The juice of infected field-grown tomato plants was found to contain in addition an autoxidizable substance whose oxidized form was capable of inactivating the virus *in vitro* in suspensions buffered at pH 7. It was concluded that the rapid oxidation in air of this autoxidizable substance is catalysed by the enzyme, and that the oxidized form of the substance inactivates the virus by direct oxidation.

The rapid inactivation of tomato spotted wilt virus in suspensions containing phenol, catechol, or quinol exposed to air received a similar explanation. In the presence of free oxygen the enzyme catalyses the oxidation of the phenols, and the oxidation products then inactivate the virus.

The bearing of these results on some plant-virus interrelationships and on the handling of suspensions of the virus is discussed.

R. J. Best. Nature *140*: 547. 1937. (Reprint 203.)

"Artificially Prepared Visible Paracrystalline Fibres of Tobacco Mosaic Virus Nucleoprotein."

Mesomorphic or paracrystalline fibres similar to those described in a previous article were prepared artifically from solutions of pure tobacco mosaic virus protein by suitably adjusting the electrolyte concentration and pH value of the solution.

R. J. Best. Aust. Chem. Inst. Jour. & Proc. *4*: 375. 1937. (Reprint 205.)

"The Chemistry of Some Plant Viruses."

A general review in which existing knowledge of the chemistry of viruses was summarized and discussed from the point of view of the nature of viruses and their possible mode of multiplication.

VII. INVESTIGATIONS ON ECONOMIC INSECTS.

D. C. Swan. Jour. Agric. Sth. Aust. *40*: 717. 1937. (Reprint 191.)

"Insects and Other Invertebrates of Economic Importance in South Australia During the Period July, 1934, to June, 1936."

This paper is the latest of a series dealing with insect and other related pests observed in South Australia. It gives brief details of their biology, the damage done, and of control methods that may be used against them. Sections are devoted to pests of crops and pastures, of horticultural crops and forests, and to those of medical and veterinary importance.

J. Davidson. Aust. Jour. Exp. Biol. & Med. Sci. *15*: 113. 1937. (Reprint 195.)

"The Temperature-Development Curve of *Lyperosia exigua* de Meijere (Diptera, Muscidae) in Relation to the Probable Distribution of this Insect in Australia."

The data relating to the velocity of development of the Buffalo Fly at different temperatures, as presented by E. Handschin (Rev. Suisse de Zool., *40*: 449, 1933) are re-examined. It is concluded that these provide insufficient material to define the temperature-development curve. The use of this curve by Handschin as an aid to the interpretation of the probable geographical distribution of the fly in Australia is discussed. It is shown that the boundaries of possible spread of *L. exigua* as defined by Tillyard and by Handschin are based on insufficient evidence; they do not adequately represent the possible ultimate range of the species. Further information is needed about the influence of temperature on all stages of the insect.

A discussion is given of the climatic factors which operate to restrict the distribution of the insect.

H. Vevers Andrewartha. Trans. Roy. Soc. Sth. Aust. *61*: 163. 1937. (Reprint 204.)

"A New Species of Thysanoptera of Economic Importance in South Australia."

This paper is a technical description of *Frankliniella lycopersici* sp. nov. This species is known to be a vector of spotted wilt of tomatoes. Specimens collected in South Australia were referred to as *Frankliniella insularis* Franklin by Morison in 1930.

H. G. Andrewartha, J. Davidson, and D. C. Swan. Jour. Agric. Sth. Aust. *41*: 565. 1938. (Reprint 215.)

"The 'Grasshopper' Problem in South Australia."

This paper discusses the biology, distribution, and control of the two major plague species in South Australia. The locust *Chortoicetes terminifera* inhabits the semi-arid pastoral country. Swarms may invade the agricultural areas at irregular intervals.

The plague grasshopper *Austroicetes cruciata* has a restricted distribution. It does not undertake long migratory flights.

Control measures depend upon an adequate knowledge of the biology and ecology of each species.

H. G. Andrewartha. Jour. Agric. Sth. Aust. *41*: 366. 1937.

"Locusts and Grasshoppers in South Australia—Some Records of Past Outbreaks."

This paper presents an interpretation of records of grasshopper outbreaks collected by the Commonwealth Meteorological Bureau between the years 1874 and 1917.

H. G. Andrewartha, J. Davidson, and D. C. Swan. Dept. Agric. Sth. Aust. Bull. 333. 1938. (Reprint 226.)

"Vegetation Types Associated with Plague 'Grasshoppers' in South Australia."

The ecology of *Chortoicetes terminifera* and *Austroicetes cruciata* is briefly outlined. Maps illustrate the distribution of the two major species and the distribution of vegetation types associated with them. The ecology of the habitats of the plague species is illustrated by a series of 55 photographs.

J. Davidson. Jour. Agric. Sth. Aust. *42*: 241. 1938. (Reprint 235.)

"The Locust and Grasshopper Problem in South Australia."

A review is made of the life-history and ecology of the two major economic species in South Australia and of their geographic ranges as established by field work. Maps are given showing survey routes taken. A general account of the progress and scope of research at present being undertaken is provided and the relation of these investigations to control measures is indicated.

VIII. CLIMATOLOGY.

J. S. Hosking. Current Science *5*: 422. (Reprint 185.)

"The Ratio of Precipitation to Saturation Deficiency of the Atmosphere in India."

For comparison with Australian data, with particular reference to the distribution of soils, the Meyer ratio of annual rainfall to atmospheric saturation deficit for Indian stations has been calculated. A map of India is presented on which the isologs of this ratio are projected.

J. A. Prescott, J. Davidson, and H. C. Trumble. Jour. Aust. Inst. Agric. Sci. *3*: 77. 1937. (Reprint 193.)

"Climatology in Relation to Biology and Agriculture."

A report based on three short addresses to the South Australian Branch of the Institute of Agricultural Science on the general principles of bioclimatology and agroclimatology.

H. C. Trumble. Trans. Roy. Soc. Sth. Aust. *61*: 41. 1937. (Reprint 197.)

"The Climatic Control of Agriculture in South Australia."

The principal climatic factors affecting the distribution of crop and herbage plants in South Australia are examined and compared with the type of agriculture practised.

The period of growth for agricultural plants is determined by the "influential rain period" which is equivalent to the period over which rainfall exceeds approximately one-third of the evaporation (E) from a free water surface of a standard 36-inch tank. Evidence is given for the use of the factor 0·3E and for the calculation of E from saturation deficiency data.

In South Australia the 5·0 months isochrone (mean annual period of influential rainfall) corresponds with the outer limits of economic wheat culture, the 7·5 months isochrone with the limits of the standard strain of subterranean clover, and the 9·0 months isochrone marks the limits of white clover and European pasture mixtures.

Maps showing the mean influential rain period in relation to wheat and pasture distribution, the amount of influential rainfall and edaphoclimatic zones of South Australia are presented.

J. A. Prescott. Jour. Aust. Inst. Agric. Sci. *4*: 33. 1938. (Reprint 218.)

"Indices in Agricultural Climatology."

In the comparison of climates simple rainfall values must be qualified to correct for the evaporating power of the air. This qualification is obtained in practice by a variety of factors and ratios in which evaporating power is

measured by evaporation from a free water surface, atmospheric saturation deficit or a function of temperature. Recorded data are examined from a number of observers on the ratio of the evaporation from bare or cropped soil to that from a free water surface. This ratio is shown to vary from 0·1 to 1·7 according to conditions, being approximately 0·3 on the average over the range field capacity to wilting point, and up to 1·7 for a heavy crop.

The usefulness of the ratios of rainfall to evaporation from a free water surface or of rainfall to saturation deficit is indicated.

Examples of recent applications are given.

J. A. Prescott. Trans. Roy. Soc. Sth. Aust. *62*: 229. 1938. (Reprint 239.)

"The Climate of Tropical Australia in Relation to Possible Agricultural Occupation."

The monthly values of the ratio of rainfall to atmospheric saturation deficit have been established for tropical Australia, and the length of the wet season determined on the basis of a minimum ratio of 5 and of the very wet season on the basis of a ratio of 35. Apart from limited areas of the Queensland coast the length of the agricultural or pastoral season varies from zero on the desert margin to 7 months in the far north.

Agriculture must therefore be restricted to short term seasonal crops, and parallels are sought in the agriculture and climate of Nigeria. The variability of the rainfall of tropical Australia is shown to be approximately twice as great as the variability in Nigeria. Temperatures in Australia are warmer in the wet season and cooler in the dry season than in Nigeria.

A range of possible crops is suggested.

IX. STATISTICAL METHOD.

E. A. Cornish and R. A. Fisher. La Revue de l'Institut International de Statistique *4*:1. 1937. (Reprint 231.)

"Moments and Cumulants in the Specification of Distributions."

The cumulants of a distribution are defined and their relationships with the ordinary moments indicated.

The symmetric function of a finite sample of observations whose mean value is equal to the corresponding cumulant of the population is defined, and a convenient expression for its evaluation in terms of the sums of powers of the sample observations is developed.

The operational properties of the cumulants are discussed, and the expansion of the probability integral of a distribution having given cumulants is derived. This expansion is transformed to a more convenient expression, which gives the value of the deviate corresponding to an assigned

level of probability in terms of the normal deviate having the same probability integral.

E. A. Cornish. Jour. Aust. Inst. Agric. Sci. *4*: 199. 1938. (Reprint 248.)
"Factorial Treatments in Incomplete Randomized Blocks."

Attention is drawn to the possibility of testing factorial treatments in balanced incomplete blocks. It is shown that the only manner in which the functions representing main effects and interactions differ from the standard expressions of orthogonal data lies in the substitution of the Q functions of the treatments for the treatment totals and the introduction of the factor kE. Similarly, the contributions of the main effects and interactions to the treatment sum of squares differ from the standard expressions only in the use of the Q's and the addition of the factor k^2E.

X. MISCELLANEOUS.

A. E. V. Richardson. Jour. Aust. Inst. Agric. Sci. *3*: 3. 1937. (Reprint 186.)
Presidential Address to Australian Institute of Agricultural Science at its First General Meeting, Sydney, 6th January, 1937.

This address deals in the first place with the debt Australia owes to its pioneers in agricultural practices, transport of foodstuffs, and plant breeding. The problems of the immediate future are seen in relation to greater efficiency in production and the need for improving the quality of our products. The need for a survey of the potential maximum productivity of Australia in relation to increases in population is indicated. The Institute should play its part in encouraging co-operative planning in the common broad fields of research.

A. E. V. Richardson. Jour. Aust. Inst. Agric. Sci. *3*: 203. 1937. (Reprint 209.)
"Agricultural Development in South Western Australia."

Report of an address to the South Australian Branch of the Institute of Agricultural Science. A survey of the climatic and soil features, the development of crop and pasture production, and of investigations in progress in relation to mineral deficiencies and other problems of this portion of Western Australia.

J. Davidson. Trans. Roy. Soc. Sth. Aust. *62*: 141. 1938. (Reprint 227.)
"On the Ecology of the Growth of the Sheep Population in South Australia."

An examination has been made of the manner of growth of the sheep population of South Australia from the beginning of the colony in 1836. The number of sheep present during each year is available; these records have been analysed and fitted to the Verhulst-Pearl logistic curve. The

influence of rainfall, the introduction of the rabbit and the development of sown perennial pastures are discussed.

The progress of sheep population during the past 100 years is discussed with reference to this curve. It illustrates that the saturation density of the sheep population which a natural pasture area can permanently carry is determined primarily by the feeding value of the pasture and the regrowth of plants eaten by the sheep. When the density exceeds this value the balance is upset, and the carrying capacity of the area will decline. The effect on the area in this respect will depend upon the degree of overgrazing and the power of the pasture to recover. In the arid areas of South Australia the recovery is mainly dependent on rainfall, and may be considerably delayed.

J. Davidson. Trans. Roy. Soc. Sth. Aust. *62*: 342. 1938. (Reprint 243.)

"On the Growth of the Sheep Population in Tasmania."

The progress of the sheep population of Tasmania from 1809 to the present day has been analysed as in the preceding paper. From 1860 to 1930 it has fluctuated about a saturation-value of 1,670,000. Compared with South Australia the rate of growth was slower. This is related to differences in the physical features, climate, and early political history of the two States. The marked temporary fluctuations in sheep numbers found in South Australia, due to drought periods, are less pronounced in the case of Tasmania.

As in the case of South Australia, the curve shows a marked new upward trend about the year 1930. This is to be attributed in each instance to the development of large areas of sown permanent pastures that commenced about this time.

D. B. Adam. Jour. Aust. Inst. Agric. Sci. *4*: 162. 1938. (Reprint 237.)

"The Injury of Grapevines by Lightning Strike."

Grapevines at Watervale, South Australia, within a roughly elliptical area about one-third of an acre, first displayed an unusual appearance in December, 1937. These symptoms, which are described in detail, taken in conjunction with local weather observations led to the conclusion that the vines were injured during a lightning storm accompanied by heavy rain, which occurred at the end of November.

D. C. Wark. Jour. Aust. Inst. Agric. Sci. *4*: 208. 1938. (Reprint 249.)

"A Method for Testing Nitrogen Deficiency."

The test is made on plants from the area selected. Thin discs from the main stem are treated with a diphenylamine reagent, and the colour produced gives an indication of the nitrogen supply.

When made during bright weather the test has given a reliable indication of the nitrogen condition of plants, but it is not applicable during dull weather.

Meteorological Records

Meteorological observations in connection with the work of the Waite Institute are being made at three centres: at the Waite Institute itself, at Pallamana in the Murray Mallee, north-west of Murray Bridge, and at Yudnapinna, north-west of Port Augusta. In these two latter centres the observations are associated with the work on pasture regeneration in the more arid regions.

At the Waite Institute readings are taken at 9 a.m. daily, and include maximum and minimum temperatures, wet and dry bulb temperatures, maximum black bulb solar temperature, rainfall, evaporation, wind mileage, and barometric pressure. In addition, self-recording instruments deal with wind direction and velocity, and with soil temperatures at depths of one inch, six inches, twelve inches, and twenty-four inches.

Since the beginning of 1938 a self-recording rain gauge has been in operation. Each hundredth of an inch of rain falling on the gauge is recorded electrically in the laboratories.

Evaporation is measured from the free water surface of an open tank, 36 inches in diameter and 36 inches deep, with a surrounding guard-ring 6 inches wide. The mean monthly values for rainfall, evaporation, and air temperatures for the three years 1936, 1937, and 1938 are given below, the individual records for the years 1925–35 having been presented in previous Reports.

Monthly Rainfall and Evaporation in Inches for the Years 1936–38, Waite Institute.

	Rainfall.			Evaporation.		
Month.	1936.	1937.	1938.	1936.	1937.	1938.
January	1·400	2·824	0·769	7·311	6·878	7·365
February	0·743	0·553	2·208	6·884	6·466	5·462
March	0·082	1·011	0·153	6·208	6·957	5·676
April	1·546	1·127	5·940	3·977	3·504	4·039
May	2·701	4·687	1·294	3·405	2·177	2·287
June	2·800	2·209	2·662	1·369	1·492	1·610
July	3·057	1·730	3·093	1·602	1·511	1·381
August	2·055	3·652	2·696	2·134	1·820	2·112
September	1·106	3·588	1·019	3·245	2·715	3·170
October	2·828	0·782	1·012	4·359	4·225	5·266
November	0·514	2·026	0·697	5·707	6·578	6·885
December	1·633	1·653	0·486	6·618	6·064	7·716
Total	20·465	25·842	22·029	52·819	50·387	52·969

Mean Monthly Air Temperatures for the Years 1936–38, Waite Institute.

Month.	Solar Max.	Screen Max.	Screen Min.	Solar Max.	Screen Max.	Screen Min.	Solar Max.	Screen Max.	Screen Min.
		1936.			1937.			1938.	
	°F.	°F.	°F.	°F.	°F	°F.	°F.	°F.	°F.
January	144·1	80·9	61·3	138·0	77·2	57·7	143·4	80·0	60·1
February	144·7	79·9	60·2	144·1	81·2	62·6	139·1	78·3	61·1
March	141·5	79·0	59·1	145·0	80·4	62·0	140·2	78·5	60·0
April	126·6	68·8	53·4	124·8	68·7	54·0	126·1	72·1	56·3
May	121·6	67·1	52·1	119·7	64·3	52·9	121·3	65·6	52·7
June	110·0	57·5	45·2	112·6	58·1	45·4	110·0	56·9	45·1
July	104·3	57·1	46·5	110·9	56·9	44·2	111·0	57·6	45·1
August	114·7	60·1	47·4	113·4	60·5	47·9	118·9	58·4	45·6
September	120·5	62·8	46·1	123·3	63·9	48·9	125·6	64·0	48·0
October	129·8	66·7	51·2	132·6	70·0	52·6	135·4	70·8	52·4
November	139·2	74·4	53·5	139·1	77·7	58·0	142·2	78·1	57·9
December	143·9	77·7	59·3	140·2	75·8	58·1	142·4	80·4	58·6
Mean	128·4	69·3	52·9	128·6	69·6	53·7	129·6	70·1	53·6

Soil Temperatures.

Temperatures in soil in bare fallow are recorded continuously by means of mercury in steel self-recording thermographs.

The mean monthly maximum and minimum soil temperatures for fourteen years are summarized in the following table:

Mean Monthly Soil Temperatures at 1 inch, 6 inches, 12 inches, and 24 inches for Fourteen Years, 1925–38, Waite Institute.

Month.	At 1"		At 6"		At 12"		At 24"	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
January	110·2	64·2	85·5	72·2	77·8	72·3	74·4	71·1
February	107·9	64·3	84·9	71·9	77·4	72·1	75·1	71·9
March	101·9	62·5	81·0	69·6	74·9	68·7	73·8	70·7
April	84·3	55·7	70·1	61·5	67·0	63·2	68·1	64·9
May	71·9	50·8	61·7	54·9	60·2	57·1	62·1	59·6
June	64·0	47·2	56·0	50·8	55·0	52·3	56·9	54·9
July	62·2	46·2	54·3	49·3	53·1	50·4	54·5	52·6
August	65·7	47·4	56·7	51·0	54·1	51·2	54·9	52·6
September	74·0	50·4	62·5	54·7	58·5	54·8	58·0	55·5
October	84·7	54·8	69·9	59·7	64·1	59·7	62·6	59·7
November	98·8	60·1	78·9	65·9	71·0	65·8	68·1	65·0
December	107·0	63·2	83·7	70·2	75·4	69·9	72·1	69·0
Mean	86·0	55·4	70·4	61·0	65·7	61·5	65·0	62·3

Number of Hours of Bright Sunshine.

The number of hours of bright sunshine is recorded daily by means of a Campbell-Stokes sunshine recorder, and is summarized in the following table:

Mean Number of Hours of Bright Sunshine per Month and per Day for Fourteen Years, 1925–38, Waite Institute.

Month.	Number of hours per day.	Number of hours per month.
January	8·7	269
February	8·5	241
March	7·4	229
April	5·6	168
May	4·4	136
June	3·4	101
July	3·3	103
August	4·3	134
September	5·6	170
October	6·5	203
November	8·2	247
December	8·4	261
Mean	6·2	Total 2,262

Wind Velocity.

Continuous records, both of the velocity and direction of the wind, have been registered since 1931 by means of the anemobiagraph.

During 1938 a cup anemometer was installed for daily routine observations, similar instruments having also been placed at Yudnapinna and Pallamana.

Daily Average Wind Velocity (in Miles per Hour) for Years 1931–38, Waite Institute.

Month	1931.	1932.	1933.	1934.	1935.	1936.	1937.	1938.	1931–38.
January	6·0	5·0	4·0	4·9	3·1	5·3	5·8	3·9	4·8
February	5·4	3·9	4·4	3·7	3·3	5·3	4·4	4·1	4·3
March	4·1	4·2	4·7	2·8	4·1	3·8	4·6	3·0	3·9
April	3·0	3·5	2·8	2·7	2·8	4·1	4·2	3·2	3·3
May	3·7	2·1	2·9	1·0	2·0	4·2	4·7	1·9	3·9
June	4·1	2·6	1·4	2·3	2·7	3·3	2·8	2·7	2·7
July	2·9	2·4	2·3	2·8	4·8	3·4	2·7	2·4	3·0
August	3·4	4·1	2·5	3·3	5·2	5·5	3·5	3·5	3·9
September	4·6	2·3	3·3	4·6	4·6	3·9	4·4	3·8	3·9
October	4·8	4·4	3·9	4·0	4·6	5·2	3·1	4·1	4·3
November	4·7	4·1	5·0	4·0	5·9	3·6	4·1	4·7	4·5
December	4·8	4·3	3·9	2·6	5·7	4·6	3·3	3·8	4·1
Mean	4·3	3·6	3·4	3·2	4·1	4·3	4·0	3·4	3·8

General Climatological Data.

The most important data on which the studies of climatology are to be based involve rainfall, evaporation, temperature, relative humidity, and atmospheric saturation deficit.

Evaporation from a free water surface is proportional, other factors being equal, to saturation deficit, and the ratios of rainfall to evaporation or to saturation

deficit have been found of special value in agroclimatological and bioclimatological studies.

The essential data for the Waite Institute, based on the mean values for the fourteen years 1925–38, are given in the following tables:

Month.	Rainfall. inches.	Evaporation. inches.	Temperature. Max. °F.	Temperature. Min. °F.	Mean. °F.	Relative humidity. per cent.	Saturation deficit. Inches of mercury.
January	0·82	8·79	80·6	59·8	70·2	52	0·36
February	1·02	7·16	81·4	60·8	71·1	54	0·35
March	0·90	6·68	78·7	59·9	69·3	53	0·34
April	1·94	4·14	70·5	54·3	62·4	63	0·20
May	3·14	2·95	64·4	50·7	57·5	68	0·15
June	3·00	1·86	58·6	46·3	52·4	76	0·10
July	3·00	1·84	57·3	45·4	51·3	76	0·09
August	3·21	2·40	59·0	45·9	52·5	71	0·12
September	2·75	3·30	63·6	48·2	55·9	67	0·15
October	1·75	4·78	68·4	50·8	59·6	62	0·20
November	1·10	6·64	74·9	55·4	65·2	55	0·28
December	1·10	8·13	78·7	57·8	68·2	53	0·33
Total	23·73	58·67	Av. 69·7	52·9	61·3	62	0·22

In the course of investigations the monthly values, ratios of rainfall to evaporation and of rainfall to saturation deficit, have proved to be most instructive. With a ratio of 1, rainfall and evaporation as measured from a free water surface are, of course, equal. A value for this ratio of 0·5 has been found to be useful in bioclimatic studies, while for agroclimatic studies ratios of 0·33 to 0·25 have been found to indicate the lower useful limit of monthly rainfall. In the case of the ratio of rainfall to saturation deficit, monthly values of 5 and 35 have been selected as representing limiting conditions. The value of 5 is just sufficient to maintain soil moisture above the wilting point of plants, while with a value of 35 transpiration from a heavy crop can be maintained.

The mean monthly values for these ratios are given below. An additional table gives the length of the season during which the above-mentioned ratios are maintained. The agricultural season may be assumed to be determined by the period during which the ratio of rainfall to evaporation exceeds 0·33.

Monthly Values of the Ratios of Rainfall to Evaporation, and of Rainfall to Saturation Deficit, Waite Institute, 1925–38.

Month.	R/E.	R/s.d.
January	0·093	2·3
February	0·142	2·9
March	0·135	2·7
April	0·469	9·7
May	1·062	20·9
June	1·614	30·0
July	1·630	33·3
August	1·341	26·8
September	0·833	18·3
October	0·366	8·8
November	0·166	3·9
December	0·135	3·3

Length of Season in Months During Which Certain Ratios of Rainfall to Evaporation and of Rainfall to Saturation Deficit are Exceeded, Waite Institute.

	R/E.	R/E.	R/E.	R/E.	R/s.d.
Ratio	1·00	0·50	0·33	0·25	5·0
Length of period (months)	3·7	5·6	6·6	7·2	7·3

The Soil Profile at the Waite Institute

The soil of the experimental fields at the Waite Institute is typical of a group of South Australian soils known as the red-brown earths. The profile has been developed on an alluvial fan at the foothills of the Mount Lofty Ranges, and the parent material is derived from the adjacent pre-Cambrian shales and slates. The surface horizon consists of a friable brown loam with a very pronounced fine sand fraction. With increase of depth the amount of organic matter falls off, and the colour of the mineral fraction predominates. The soil gradually changes to a reddish-brown at 12–18 inches, while the deep clay is red.

Eluviation has not been sufficient to remove the calcium carbonate entirely from the lower horizons of the profile, although the surface soil is weakly podsolized. The reaction of the surface soil is pH 6·0 to 6·3, while that of the carbonate horizon may reach pH 8·6.

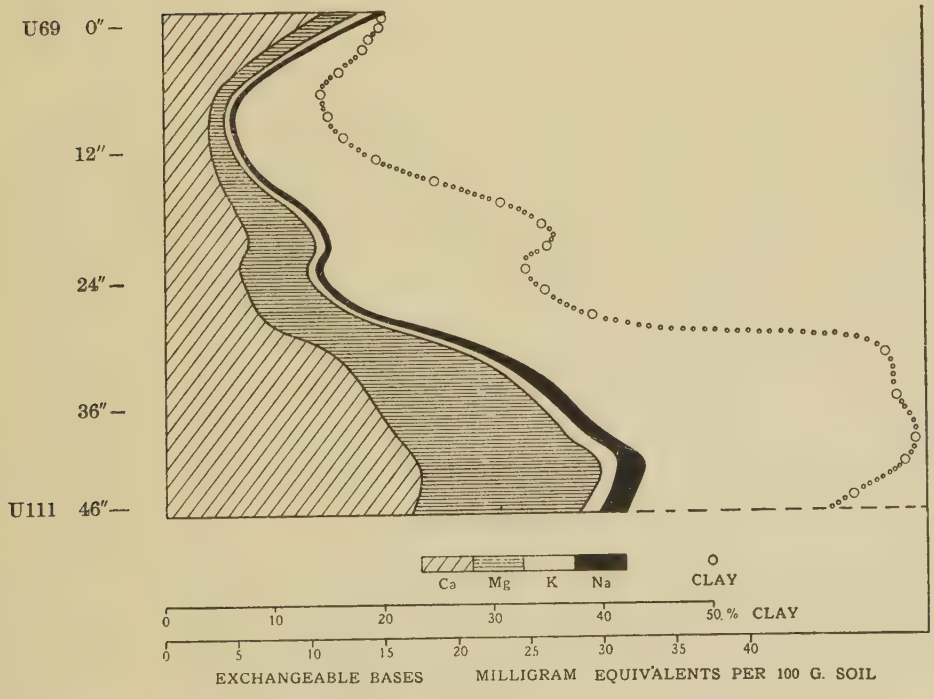
The mechanical composition of two profiles is shown in the first diagram. The first profile was sampled in considerable detail, and shows an initial decrease in the clay content of the top few inches. Both profiles then show a well-defined illuvial zone of heavy clay. Below this illuvial horizon the amount of clay again decreases, and at this point calcium carbonate appears in the profile, having been completely leached from the overlying A and B_1 horizons.

The nearly constant proportion of coarse sand, fine sand and silt throughout the profile shows clearly the uniform nature of the original parent material. These three fractions constitute the non-colloidal framework of the soil and their constant proportion shows that the changes in the colloidal fraction (clay) of the different horizons has been brought about by a process of eluviation. The accumulation of clay in the B_1 horizon has occurred as a result of its dispersion and mechanical eluviation under the slightly acid conditions existing in the surface soil. An examination of the silica : sesquioxide ratios shows that there has been only a small amount of leaching of the sesquioxides from the surface layers into the lower horizons. The amount of free ferric oxide in the different parts of the profile also shows that there has been little actual decomposition of the clay to silica and sesquioxide, as occurs in podsols.

Organic carbon and nitrogen decrease progressively throughout the profile, and the carbon : nitrogen ratio changes from about 13 in the surface horizon to a value of 7–8 at a depth.

Although the soils are somewhat unsaturated with bases in the surface horizons, the values ranging from 60–65 per cent. of full saturation, the percentage saturation increases progressively with depth, and the horizons below the appearance of calcium carbonate are fully base saturated. Calcium is the dominant ex-

INCHES
0 5 10 15 20 25 30 35 40 45 50
COARSE SAND
FINE SAND
SILT
CLAY
0 10 20 30 40 50 60 70 80 90 100 %


U69 0″
12″
24″
36″
U111 46″
Ca
Mg
K
Na
CLAY
0 10 20 30 40 50 % CLAY
0 5 10 15 20 25 30 35 40
EXCHANGEABLE BASES MILLIGRAM EQUIVALENTS PER 100 G. SOIL

changeable base in the surface soil, and accounts for the good texture in the field. The proportion of magnesium, however, increases considerably in the subsoil. Exchangeable sodium is low throughout the profile, indicating that the leaching conditions and calcium status of the soil are sufficiently good to remove cyclic salts, without an accumulation of exchangeable sodium. The quantities of exchangeable potassium indicate that the soil is well supplied with this element in a form available for plant growth. The clay content and the amounts of the exchangeable bases are shown for an inch-by-inch profile in the second diagram.

The Mechanical and Chemical Analyses of a Typical Red-Brown Earth Profile at the Waite Institute.

Locality.		Hd. Adelaide, Section 250.						
Soil No.		U 151	U 152	U 153	U 154	U 155	U 156	U 157
Depth		0–4″	4–9″	9–18″	18–27″	27–36″	26–45″	45–54″
Horizon		A_1	A_2	B_1	B_1	B_1	B_2C	B_2C
Reaction	pH	6·0	5·8	6·3	6·7	7·2	8·4	8·6
		%	%	%	%	%	%	%
Calcium Carbonate	$CaCO_3$	0·02	tr.	0·01	nil	0·13	4·80	3·96
Mechanical Analysis:								
Coarse Sand		2·1	1·9	1·2	0·7	0·6	0·8	1·3
Fine Sand		43·7	40·8	26·3	18·6	19·2	24·5	25·3
Silt		34·8	33·8	22·8	18·8	19·3	28·4	29·7
Clay		18·0	21·8	47·4	59·9	59·2	40·7	37·2
Loss on Acid Treatment		1·0	0·7	1·1	1·4	1·6	6·3	5·2
Moisture		0·4	0·6	1·2	2·0	1·7	1·2	1·1
Chemical Data:								
Loss on Ignition		4·4	4·1	6·2	7·3	7·2	7·3	6·7
Organic Carbon	C	1·32	1·07	0·76	0·67	0·66	0·41	0·30
Humus		1·53	1·02	0·59	0·41	0·45	0·34	0·26
Free Iron Oxide	Fe_2O_3	2·14	2·46	4·68	5·17	4·72	3·42	3·34
Nitrogen	N	0·103	0·091	0·084	0·077	0·073	0·046	0·035
Phosphoric Acid	P_2O_5	0·047	0·046	0·051	0·050	0·045	0·032	0·028
Potash	K_2O	0·52	0·59	0·93	1·11	1·08	0·90	0·93
Chlorides	as NaCl	0·013	0·008	0·008	0·010	0·012	0·015	0·016
Reactive Manganese	Mn	430*	390*	180*	110*	120*	180*	230*
Exchangeable Bases:		m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †	m.e.% †
Calcium	Ca	4·49 64	4·87 65	8·88 59	13·16 57	15·07 60	17·74 71	15·87 68
Magnesium	Mg	1·36 19	1·69 23	4·81 32	7·77 34	8·04 32	5·56 22	5·94 25
Potassium	K	0·83 12	0·65 9	0·97 6	1·31 6	1·36 5	1·04 4	0·97 4
Sodium	Na	0·32 5	0·23 3	0·46 3	0·66 3	0·66 3	0·64 3	0·80 3
Total Bases		7·00 100	7·44 100	15·12 100	22·90 100	25·13 100	24·98 100	23·58 100
Exchangeable Hydrogen	H	5·2	5·2	6·4	6·5	5·4	0·9	0·5
Percentage Base Saturation		57	59	70	78	82	97	98
Composition of Clay Fraction:								
$\frac{SiO_2}{Al_2O_3}$		3·43	3·27	2·86	2·85	2·86	3·16	3·22
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$		2·53	2·41	2·13	2·12	2·13	2·32	2·34

* Parts per million.
m.e.% Milligram equivalents per 100 grm. of soil.
† Percentage composition of the bases.

Records of Field Experimental Work

LIST OF FIELD EXPERIMENT RECORDS.

1. Permanent Rotation Tests, 1925–38.
2. Effect of Sulphate of Ammonia on the Yield of Oats.
3. Effect of Sulphate of Ammonia on the Yield of Barley.
4. Effect of Grazing and Harvesting Forage Crops on the Yield of Wheat in Four Course Rotations.
5. Effect of Superphosphate, Nitrogen, and Lime on Wheat, Oats, Barley, and Peas in Four Course Rotations.
6. Effect of Time of Sowing, Seed Rate, and Sulphate of Ammonia on the Yield of Canary Grass (*Phalaris canariensis*) 1936.
7. Effect of Time of Sowing, Seed Rate, and Sulphate of Ammonia on the Yield of Flax.
8. Effect of Time of Sowing, Seed Rate, and Superphosphate on the Yield of Flax.
9. Effect of Top-dressing on the Yield of Natural Pasture.
10. Effect of Different Systems of Management on the Yield of a Seeded Permanent Pasture.
11. Effect of Superphosphate and Surface Cultivation on the Yield and Botanical Composition of a Seeded Pasture.
12. Effect of Differential Grazing Management on a Seeded Pasture.
13. Comparison of the Grazing Value of Top-dressed Natural and Seeded Pastures at (1) Waite Institute, (2) Kybybolite.
14. Yield Trial of New Crossbred Wheats, 1936.
15. Yield Trial of New Crossbred Wheats, 1937.
16. Yield Trial of New Crossbred Wheats, 1938.

A NOTE ON THE CONSTRUCTION AND USE OF THE SUMMARY TABLES.

Yields of Seed in cwt. per ac. Mean of all Nitrogen ±0·171.

Time of sowing.	Seed rate in lb. per ac. 16	24	Mean ±0·374.	Increase ±0·529.
E	14·73	14·68	**14·70**	*7·55*
L	6·80	7·50	**7·15**	—
Mean ±0·121	**10·77**	**11·09**	**10·93**	—
Increase ±0·171	—	*0·32*	—	—

In this table and others of similar construction, the numbers in ordinary type are the mean yields of the treatments indicated at the headings of the columns and the left-hand margins of the rows. Thus 14·73 is the yield of seed in cwt. per ac. averaged over all nitrogen treatments and all plots sown early at 16 lb. per ac. The numbers in heavy type denote more general averages. Thus 14·70 is the yield in cwt. per ac. averaged over all nitrogen treatments and all seed rates of the plots sown early. The general mean of all treatments is 10·93 cwt. per ac. The numbers in italics preceded by a — sign denote decreases.

The standard errors (prefaced by the sign ±) applicable to all comparisons of likely interest are included in the tables. As a general rule, it may be taken that a quantity is significant if it exceeds twice its standard error. Thus the mean increase in favour of early sowing, 7·55 ±0·529, is definitely significant. The average increase due to the higher seed rate, 0·32 ±0·171, is not significant.

In testing the difference between two quantities having the same standard error, it may be assumed that the difference is significant if it exceeds three times that standard error. Thus the difference between 7·50 and 6·80 is 0·70, and since this exceeds three times 0·171 there is a significant increase in yield due to the higher seed rate when the crop is sown late.

The areas of plots given in the tables denote areas at harvest. Unless otherwise specified, the experiments have been conducted at the Waite Institute.

1. PERMANENT ROTATION TESTS.

Effect of different crop rotations on the yield of wheat.

Variety of crop and seed rate per ac.:

Wheat, Sepoy, 90 lb.
Oats, Early Burt, 70 lb.
Barley, Pryor, 80 lb.
Peas, White Brunswick, 150 lb.
Pasture, Wimmera rye-grass, 15 lb.
Sudan grass, 15 lb.

Basal dressing of 94 lb. per ac. superphosphate 1925–28, 187 lb. per ac. 1929–38.

Design: 31 plots, grouped in 12 rotations, so that each course of the 12 rotations is represented every year. Rotations given in the table.

Area of plot = 1/7th acre.

Mean Yields for Seasons 1926–38.

Crop Rotation.	Wheat (bush. per ac.).	Oats (bush. per ac.).	Barley (bush. per ac.).	Peas (bush. per ac.).	Temporary Pasture (cwt. per ac. of dry hay).
1. Wheat, fallow	34·70	—	—	—	—
2. Wheat, peas	28·04	—	—	17·61	—
3. Wheat, pasture, fallow ..	39·00	—	—	—	24·81
4. Wheat, oats, fallow ..	37·71	48·31	—	—	—
5. Wheat, peas, fallow ..	39·69	—	—	25·37	—
6. Wheat, barley, fallow ..	39·19	—	49·02	—	—
7. Wheat continuously ..	16·46	—	—	—	—
8. Wheat, oats, peas ..	31·97	40·30	—	25·88	—
9. Wheat, barley, peas ..	33·57	—	47·07	26·46	—
10. Wheat, oats, pasture fallow	44·82	57·01	—	—	28·32
11. Wheat, Sudan grass ..	34·70	—	—	—	21·08*
12. Wheat, fallow	38·33	—	—	—	—

* Sudan grass in cwt. per ac. green fodder.

2. EFFECT OF SULPHATE OF AMMONIA ON THE YIELD OF OATS.

Variety:

Early Burt, 60 lb. per ac. sown on wheat stubble.

Treatments:

A. No nitrogen.
B. ½ cwt. per ac. sulphate of ammonia at seeding.
C. 1 ,, ,, ,,
D. 2 ,, ,, ,,
E. 3 ,, ,, ,,
F. 1 ,, ,, in spring.

Basal dressing of 2 cwt. per ac. superphosphate.

Design:

Treatments arranged in a Latin square.
Area of plot = $\frac{1}{25}$th acre.

Mean yields of grain in bushels per ac. ±1·104.

	Treatment.						
Year.	A	B	C	D	E	F	Mean.
1933	34·58	43·49	55·13	77·66	85·16	54·27	**58·38**
1934	47·24	56·88	64·17	72·37	75·49	63·59	**63·29**
1935	31·48	37·06	43·57	54·77	62·11	50·99	**46·66**
1936	30·51	37·58	47·02	58·89	61·43	49·38	**47·47**
1937	19·95	26·85	37·40	60·86	77·19	39·30	**43·59**
Mean ±0·494	**32·75**	**40·37**	**49·46**	**64·91**	**72·28**	**51·51**	**51·88**

Mean yields of total produce in cwt. per ac. ±1·016.

	Treatment.						
Year.	A	B	C	D	E	F	Mean.
1933	23·37	31·41	43·42	65·24	76·90	41·08	**46·90**
1934	34·39	42·49	49·39	56·79	63·47	47·75	**49·05**
1935	28·22	34·82	43·14	59·82	68·82	44·92	**46·62**
1936	21·99	29·06	38·72	51·58	55·54	37·13	**38·99**
1937	14·25	20·50	30·52	54·58	72·28	32·71	**37·47**
Mean ±0·454	**24·43**	**31·66**	**41·04**	**57·60**	**67·40**	**40·72**	**43·81**

3. EFFECT OF SULPHATE OF AMMONIA ON THE YIELD OF BARLEY.

Variety: Pryor, 80 lb. per ac. sown on oat stubble.

Treatments:

A. No nitrogen.
B. ½ cwt. per ac. sulphate of ammonia at seeding.
C. 1 „ „ „
D. 2 „ „ „
E. 3 „ „ „
F. 1 „ „ in spring.

Basal dressing of 2 cwt. per ac. superphosphate.

Design:

Treatments arranged in a Latin square.

Area of plot = $\frac{1}{25}$th acre.

Mean yields of grain in bushels per ac. ±1·135.

	Treatment.						
Year.	A	B	C	D	E	F	Mean.
1933	28·71	38·33	48·60	60·40	65·17	48·23	**48·24**
1934	24·48	30·69	39·31	51·02	58·77	38·87	**40·52**
1935	32·81	39·25	47·75	61·79	66·08	46·04	**48·95**
1936	22·08	26·23	33·81	44·98	55·37	31·35	**35·64**
1937	28·23	37·92	45·19	56·35	53·02	43·54	**44·04**
Mean ±0·507	**27·26**	**34·48**	**42·93**	**54·91**	**59·68**	**41·61**	**43·48**

Mean yields of total produce in cwt. per ac. ±1·136.

	Treatment.						
Year.	A	B	C	D	E	F	Mean.
1933	24·76	34·24	45·72	59·27	65·95	44·03	**45·66**
1934	20·83	26·84	35·46	48·38	57·13	34·77	**37·24**
1935	27·55	34·52	42·47	54·80	60·21	40·35	**43·32**
1936	18·97	24·11	32·11	44·08	53·09	27·42	**33·30**
1937	25·09	35·08	42·57	57·26	58·42	41·78	**43·37**
Mean ±0·508	**23·44**	**30·96**	**39·67**	**52·76**	**58·96**	**37·67**	**40·58**

4. EFFECT OF GRAZING AND HARVESTING FORAGE CROPS ON THE YIELD OF WHEAT IN FOUR-COURSE ROTATIONS.

Variety of crop and seed rate per ac.:

Wheat, Sepoy Selection, 90 lb.
Barley, Cape, 80 lb.
Oats, Mulga, 70 lb.
Peas, White Brunswick, 150 lb.
Subterranean clover, Mount Barker, 10 lb.
Wimmera rye-grass, 10 lb.

Rotations:

A	B	C	D	E
Fallow	Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat	Wheat
Peas	Clover	Barley	Oats	Fallow
Pasture	Pasture	Pasture	Pasture	Wheat

Manurial treatment: Basal dressing of 2 cwt. per ac. superphosphate applied to all crops except pasture.

Forage crop treatment: Grazed = G.
Harvested = H.

Design: 60 main plots divided into 4 groups of 15 plots; each course of the rotation is represented in every year by 15 plots. Each group of 15 plots is divided into 3 randomized blocks of 5 plots on each, of which the 5 rotations are represented. The main plots are subdivided into halves to assess the differential effects of grazing and harvesting the forage crops.

Area of main plot = $\frac{1}{6}$ .94 acre.

		Rotation.									
		A		B		C		D		E	
		G	H	G	H	G	H	G	H	G	H
Wheat, grain in bush. per ac.	1937	43·75	43·71	37·17	39·39	40·16	39·93	38·66	43·15	40·01	39·26
	1938	39·64	42·01	37·71	39·49	39·68	40·99	37·54	39·89	30·51	32·20
Forage crop, total produce cwt. per ac.	1937	55·37	49·89	25·07	24·11	17·92	19·80	15·84	20·11	—	—
	1938	42·09	41·67	16·98	10·27	13·44	29·82	13·22	25·62	—	—
Pasture cwt. per ac.	1937	33·23*		19·28*		19·41*		18·14*		36·61†	34·83†
	1938	30·05	20·67	22·77	19·30	13·66	8·41	11·18	8·44	33·18†	29·85†

* No differential treatment of the forage crops in 1936.
† Wheat crop corresponding to the pasture in rotations A, B, C and D.

5. EFFECT OF SUPERPHOSPHATE, NITROGEN, AND LIME ON WHEAT, OATS, BARLEY, AND PEAS IN FOUR-COURSE ROTATIONS.

Variety of crop and seed rate per ac.:

Wheat, Sepoy Selection, 90 lb.
Oats, Mulga, 70 lb.
Barley, Pryor, 80 lb.
Peas, White Brunswick, 130 lb.
Pasture, Wimmera rye-grass, 3 lb.
„ Early subterranean clover, 6 lb.

Rotations:

A	B	C	D
Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat
Peas	Oats	Barley	Wheat
Pasture	Pasture	Pasture	Pasture

Superphosphate: None = P_0, 1 cwt. per ac. = P_1, 2 cwt. per ac. = P_2.

Sulphate of ammonia: None = N_0, 1 cwt. per ac. = N_1, 2 cwt. per ac. = N_2.

Lime: None = L_0, $2\frac{1}{2}$ cwt. per ac. = L_1, 5 cwt. per ac. = L_2.

Manurial treatment: All combinations of superphosphate, sulphate of ammonia, and lime applied to the cereal crops and peas, but not to the pasture.

Design: 432 plots divided into 4 groups of 108 plots for the 4 rotations. Each group of 108 plots subdivided into 4 sections of 27 plots, and each course of the rotations is represented by a section of 27 plots every year. Each section of 27 plots is subdivided into 3 randomized blocks of 9 plots for the application of the manurial treatment. This subdivision confounds a pair of degrees of freedom for second order interaction with soil differences.

Area of plot = $\frac{1}{77}$th acre.

Rotation A.

Wheat: Yield of grain in bushels per ac. 1937.

	Mean of all lime.			Mean of all nitrogen.				Mean of all phosphate.			
	N_0	N_1	N_2	L_0	L_1	L_2	Mean		N_0	N_1	N_2
P_0	44·60	48·55	45·77	43·42	48·13	47·38	**46·31**	L_0	48·55	47·06	46·09
P_1	51·44	48·87	47·70	48·02	48·66	51·33	**49·34**	L_1	48·77	49·30	49·41
P_2	51·12	50·80	49·19	50·26	50·69	50·16	**50·37**	L_2	49·84	51·87	47·16
Mean	**49·05**	**49·41**	**47·55**	**47·23**	**49·16**	**49·62**	**48·67**				

Wheat: Yield of grain in bushels per ac. 1938.

P_0	42·80	42·80	40·01	41·90	41·90	41·81	**41·87**	L_0	41·41	44·20	42·30
P_1	43·40	43·70	41·21	41·81	41·31	45·20	**42·77**	L_1	43·10	42·20	39·41
P_2	43·40	42·20	41·90	44·20	41·51	41·81	**42·50**	L_2	45·10	42·30	41·41
Mean	**43·20**	**42·90**	**41·04**	**42·64**	**41·57**	**42·94**	**42·38**				

Peas: Yield of grain in bushels per ac. 1937.

P_0	19·57	23·31	25·35	25·77	22·89	19·57	**22·74**	L_0	32·30	32·30	29·20
P_1	32·73	29·52	28·23	32·19	30·69	27·59	**30·16**	L_1	30·16	26·42	30·91
P_2	37·97	31·87	33·90	35·83	33·90	34·01	**34·58**	L_2	27·81	25·99	27·38
Mean	**30·09**	**28·23**	**29·16**	**31·26**	**29·16**	**27·06**	**29·16**				

Peas: Yield of grain in bushels per ac. 1938.

P_0	34·82	30·43	31·53	31·33	33·03	32·43	**32·26**	L_0	32·73	30·43	28·44
P_1	30·73	33·03	30·33	30·93	31·83	31·33	**31·36**	L_1	30·63	31·93	30·33
P_2	30·73	29·93	27·24	29·33	28·04	30·53	**29·30**	L_2	32·93	31·03	30·33
Mean	**32·09**	**31·13**	**29·70**	**30·53**	**30·96**	**31·43**	**30·97**				

Rotation B.

Wheat: Yield of grain in bushels per ac. 1936.

P_0	28·55	32·51	36·68	32·73	31·12	33·90	**32·58**	L_0	29·52	33·79	37·43
P_1	34·12	32·30	40·32	35·61	34·86	36·25	**35·58**	L_1	31·44	32·40	39·57
P_2	29·62	37·43	39·36	32·40	37·43	36·58	**35·47**	L_2	31·33	36·04	39·36
Mean	**30·76**	**34·08**	**38·79**	**33·58**	**34·47**	**35·58**	**34·54**				

Wheat: Yield of grain in bushels per ac. 1937.

P_0	36·36	34·01	35·18	34·01	35·51	36·04	**35·18**	L_0	42·35	42·67	40·00
P_1	44·38	45·67	44·49	45·45	43·21	45·88	**44·85**	L_1	44·49	41·07	40·21
P_2	48·66	46·73	44·28	45·59	47·06	47·06	**46·56**	L_2	42·56	42·67	43·74
Mean	**43·13**	**42·14**	**41·32**	**41·67**	**41·92**	**42·99**	**42·20**				

Wheat: Yield of grain in bushels per ac. 1938.

P_0	38·98	38·57	35·10	35·82	37·04	39·80	**37·55**	L_0	42·35	43·47	39·69
P_1	42·55	44·08	44·08	43·78	42·55	44·39	**43·57**	L_1	41·02	40·71	42·14
P_2	44·29	45·61	45·71	45·92	44·29	45·41	**45·20**	L_2	42·45	44·08	43·06
Mean	**41·94**	**42·75**	**41·63**	**41·84**	**41·29**	**43·20**	**42·11**				

Oats: Yield of grain in bushels per ac. 1936.

P_0	50·69	58·07	66·41	58·07	58·71	58·39	**58·39**	L_0	52·62	61·76	70·42
P_1	51·01	61·28	73·47	60·96	60·64	64·17	**61·92**	L_1	53·90	60·80	67·38
P_2	55·66	66·25	68·34	65·77	62·72	61·76	**63·42**	L_2	50·85	63·04	70·42
Mean	**52·46**	**61·87**	**69·41**	**61·60**	**60·69**	**61·44**	**61·24**				

Oats: Yield of grain in bushels per ac. 1937.

	Mean of all lime.			Mean of all nitrogen.				Mean of all phosphate.			
	N_0	N_1	N_2	L_0	L_1	L_2	Mean		N_0	N_1	N_2
P_0	52·46	64·81	82·45	69·30	65·61	64·81	**66·57**	L_0	52·14	64·33	90·48
P_1	55·66	66·89	85·98	70·10	71·39	67·05	**69·51**	L_1	56·95	64·97	85·82
P_2	55·50	66·25	85·34	67·54	70·74	68·82	**69·03**	L_2	54·54	68·66	77·48
Mean	**54·54**	**65·98**	**84·59**	**68·98**	**69·25**	**66·89**	**68·37**				

Oats: Yield of grain in bushels per ac. 1938.

P_0	58·32	70·56	73·62	70·56	67·35	64·59	**67·50**	L_0	63·49	73·01	78·38
P_1	65·36	74·85	76·07	73·01	71·79	71·48	**72·09**	L_1	63·06	70·71	73·93
P_2	63·06	71·79	76·99	71·33	68·57	71·94	**70·61**	L_2	60·15	73·48	74·39
Mean	**62·24**	**72·40**	**75·56**	**71·63**	**69·23**	**69·34**	**70·07**				

Rotation C.

Wheat: Yield of grain in bushels per ac. 1936.

P_0	22·78	26·63	26·74	24·17	26·42	25·56	**25·38**	L_0	25·88	31·33	33·69
P_1	30·27	34·65	34·33	33·05	31·55	34·65	**33·08**	L_1	28·23	34·22	32·08
P_2	30·69	37·86	39·30	33·69	36·58	37·59	**35·95**	L_2	29·62	33·58	34·60
Mean	**27·91**	**33·05**	**33·46**	**30·30**	**31·51**	**32·60**	**31·47**				

Wheat: Yield of grain in bushels per ac. 1937.

P_0	28·77	30·27	29·62	29·62	30·80	28·23	**29·55**	L_0	43·53	38·29	35·72
P_1	44·28	45·34	41·92	42·46	43·21	45·88	**43·85**	L_1	37·75	40·32	39·89
P_2	49·94	48·45	42·46	45·45	43·95	51·44	**46·95**	L_2	41·71	45·45	38·39
Mean	**41·00**	**41·35**	**38·00**	**39·18**	**39·32**	**41·85**	**40·12**				

Wheat: Yield of grain in bushels per ac. 1938.

P_0	39·69	35·92	37·14	35·92	38·67	38·16	**37·58**	L_0	41·22	40·82	40·00
P_1	43·16	44·39	43·16	42·86	44·08	43·78	**43·57**	L_1	43·57	41·94	41·22
P_2	43·67	44·08	43·78	43·27	43·98	44·29	**43·84**	L_2	41·73	41·63	42·86
Mean	**42·18**	**41·46**	**41·36**	**40·68**	**42·24**	**42·07**	**41·67**				

Barley: Yield of grain in bushels per ac. 1936.

P_0	32·98	47·35	50·43	42·22	47·23	41·32	**43·59**	L_0	42·73	46·07	56·34
P_1	46·46	48·00	56·59	46·20	52·10	52·74	**50·35**	L_1	47·23	53·26	56·08
P_2	50·95	55·18	59·03	56·72	57·24	51·20	**55·05**	L_2	40·24	51·20	53·64
Mean	**43·46**	**50·18**	**55·35**	**48·38**	**52·19**	**48·42**	**49·66**				

Barley: Yield of grain in bushels per ac. 1937.

P_0	47·35	48·12	52·10	51·08	48·25	48·25	**49·19**	L_0	42·35	49·15	55·31
P_1	41·84	49·54	60·19	52·23	50·69	48·64	**50·52**	L_1	42·61	48·38	58·07
P_2	38·11	46·20	58·39	43·50	50·05	49·15	**47·57**	L_2	42·35	46·33	57·36
Mean	**42·44**	**47·95**	**56·89**	**48·94**	**49·66**	**48·68**	**49·09**				

Barley: Yield of grain in bushels per ac. 1938.

P_0	42·37	48·86	51·43	49·10	48·24	45·31	**47·55**	L_0	47·39	51·67	53·26
P_1	45·18	53·14	49·71	51·18	48·00	48·86	**49·35**	L_1	41·88	50·82	53·26
P_2	47·39	50·45	51·06	52·04	49·71	47·14	**49·63**	L_2	45·67	49·96	45·67
Mean	**44·98**	**50·82**	**50·73**	**50·78**	**48·65**	**47·10**	**48·84**				

Rotation D.

Wheat (1st crop): Yield of grain in bushels per ac. 1937.

	Mean of all lime.			Mean of all nitrogen.				Mean of all phosphate.			
	N_0	N_1	N_2	L_0	L_1	L_2	Mean		N_0	N_1	N_2
P_0	39·78	41·60	42·88	41·92	42·14	40·21	**41·42**	L_0	41·60	42·67	43·31
P_1	40·96	42·88	45·88	41·82	44·38	43·53	**43·24**	L_1	40·43	43·10	45·88
P_2	40·10	43·42	46·41	43·85	42·88	43·21	**43·31**	L_2	38·82	42·14	45·99
Mean	**40·28**	**42·64**	**45·06**	**42·53**	**43·13**	**42·31**	**42·66**				

Wheat (1st crop): Yield of grain in bushels per ac. 1938.

P_0	43·90	45·60	42·70	43·60	44·00	44·60	**44·07**	L_0	46·00	45·70	44·00
P_1	45·80	46·89	46·39	47·59	45·00	46·49	**46·36**	L_1	45·60	46·69	41·81
P_2	46·10	45·50	42·10	44·50	45·10	44·10	**44·57**	L_2	44·20	45·60	45·40
Mean	**45·26**	**46·00**	**43·73**	**45·23**	**44·70**	**45·06**	**45·00**				

Wheat (2nd crop): Yield of grain in bushels per ac. 1937.

P_0	32·08	39·46	41·92	37·75	40·64	35·08	**37·82**	L_0	38·93	39·25	44·38
P_1	35·29	43·53	46·41	42·35	41·60	41·28	**41·74**	L_1	37·22	40·96	45·24
P_2	42·88	39·57	45·56	42·46	41·17	44·38	**42·67**	L_2	34·12	42·35	44·28
Mean	**36·75**	**40·85**	**44·63**	**40·85**	**41·14**	**40·25**	**40·75**				

Wheat (2nd crop): Yield of grain in bushels per ac. 1938.

P_0	35·12	38·21	39·81	38·41	36·72	38·01	**37·71**	L_0	36·72	40·71	42·20
P_1	37·22	42·90	43·70	40·61	42·30	40·91	**41·27**	L_1	37·61	41·31	42·90
P_2	37·91	42·60	45·90	40·61	42·80	43·00	**42·14**	L_2	35·92	41·71	44·30
Mean	**36·75**	**41·24**	**43·14**	**39·88**	**40·61**	**40·64**	**40·38**				

Yield of temporary pasture 1938: cwt. per ac. of air-dry hay.

Rotation A.

Following application of manurial treatments in 1937.

N_0	28·49	P_0	29·20	L_0	29·87
N_1	30·24	P_1	30·23	L_1	30·03
N_2	30·57	P_2	29·87	L_2	29·40

Rotation B.

Following application of manurial treatments in 1936 and 1937.

N_0	20·07	P_0	17·84	L_0	19·27
N_1	17·89	P_1	19·43	L_1	19·87
N_2	20·76	P_2	21·45	L_2	19·58

Rotation C.

Following application of manurial treatments in 1936 and 1937.

N_0	20·07	P_0	18·70	L_0	19·85
N_1	21·09	P_1	20·80	L_1	20·56
N_2	21·69	P_2	23·35	L_2	22·44

Rotation D.

Following application of manurial treatments in 1937.

N_0	22·27	P_0	21·31	L_0	21·62
N_1	21·51	P_1	20·71	L_1	21·29
N_2	21·65	P_2	23·41	L_2	22·53

6. EFFECT OF TIME OF SOWING, SEED RATE, AND SULPHATE OF AMMONIA ON THE YIELD OF CANARY GRASS *(PHALARIS CANARIENSIS)*, 1936.

Seed rates: 16 and 24 lb. per ac.

Time of sowing: Early, 18th June = E. } On canary grass stubble.
Late, 20th July = L. }

Manurial treatment: Sulphate of ammonia, none and 1 cwt. per ac.
Basal dressing of 2 cwt. per ac. superphosphate.

Treatments: All combinations of time of sowing, seed rate, and nitrogen.

Design: 6 randomized blocks of early and late sowing treatments; all combinations of seed rate and nitrogen randomized within each main plot.

Area of main plot = $\frac{4}{50}$th acre; area of sub-plot = $\frac{1}{50}$th acre.

Yields of seed in cwt. per ac. Mean of all nitrogen ±0·171.

Time of sowing.	Seed rate: lb. per ac. 16	24	Mean ±0·374	Increase ±0·529
E	14·73	14·68	**14·70**	*7·55*
L	6·80	7·50	**7·15**	—
Mean ±0·121	**10·77**	**11·09**	**10·93**	—
Increase ±0·171	—	*0·32*	—	—

S.E. of difference between 2 means of 12 plots = ±0·242 cwt. per ac.

Difference in favour of early sowing significant: interaction of seed rate and time of sowing also significant: with early sowing there is no difference in yield with increase in seed rate, but with late sowing there is a significant increase with increase in seed rate.

Yield of total produce in cwt. per ac. Mean of all nitrogen ±0·628.

Time of sowing.	Seed rate: lb. per ac. 16	24	Mean ±1·569	Increase ±2·218
E	61·29	63·48	**62·38**	*36·38*
L	24·42	27·59	**26·00**	—
Mean ±0·444	**42·86**	**45·53**	**44·19**	—
Increase ±0·628	—	*2·67*	—	—

Difference in favour of early sowing is significant: similarly with difference in favour of the heavier seed rate: interaction insignificant.

7. EFFECT OF TIME OF SOWING, SEED RATE, AND SULPHATE OF AMMONIA ON THE YIELD OF FLAX.

Variety: Liral Crown.
Seed rates: 40, 60, 80 and 100 lb. per ac.
Sulphate of ammonia: None = N_0, 2 cwt. per ac. = N_2.
Basal dressing of 2 cwt. per ac. superphosphate.
Time of sowing: Early, 21st May = E.
Late, 22nd June = L.
Treatments: All combinations of seed rate, time of sowing and nitrogen.
Design: 4 randomized blocks of early and late sowing treatments; all combinations of seed rate and nitrogen randomized within each main plot.
Area of main plot = $\frac{8}{50}$th acre; area of sub-plot = $\frac{1}{50}$th acre.

Mean yields of seed in bushels per ac. ±0·589.

	Seed rate: lb. per ac.									
	40		60		80		100		Mean	Increase
	E	L	E	L	E	L	E	L	±0·208	±0·294
N_0	13·58	7·81	11·99	7·67	9·75	7·50	11·05	5·38	9·34	—
N_2	12·24	7·42	11·83	5·56	10·83	5·52	9·77	3·77	8·37	*—0·97*
Mean ± 0·416	12·91	7·62	11·91	6·61	10·29	6·51	10·41	4·57	—	—
Mean ± 0·294	10·26		9·26		8·40		7·49		8·85	—
Increase ± 0·416	—		*—1·00*		*—0·86*		*—0·91*		—	—

Significant depression in presence of N; significant decreases with the higher seed rates; significant increase in favour of early sowing.

Mean of early sowing 11·38 ±0·435
Mean of late sowing 6·33 ±0·435 Increase 5·05 ±0·615.

Mean yields of total produce in cwt. per ac. Mean of all seed rates ±0·762.

	Nitrogen			
Time of sowing	N_0	N_2	Mean ±1·412	Increase ±1·997
E	50·60	60·03	**55·32**	—
L	38·44	40·70	**39·57**	*—15·75*
Mean ±0·539	**44·52**	**50·37**	**47·44**	—
Increase ±0·762	—	*5·85*	—	—

Significant difference in favour of early sowing and application of nitrogen: significant interaction of time of sowing and nitrogen.

Mean yields of total produce in cwt. per ac. Mean of times of sowing ±1·077.

	Seed rate: lb. per ac.				Mean	Increase
Nitrogen	40	60	80	100	±0·539	±0·762
N_0	42·45	43·23	46·20	46·19	**44·52**	—
N_2	46·30	50·22	53·44	51·52	**50·37**	*5·85*
Mean ±0·762	**44·38**	**46·73**	**49·82**	**48·85**	**47·44**	—
Increase ±1·077	—	*2·35*	*3·09*	*—0·97*	—	—

Significant increases with the higher seed rates.

8. EFFECT OF TIME OF SOWING, SEED RATE, AND SUPERPHOSPHATE ON THE YIELD OF FLAX.

Variety: Liral Crown.
Seed rate: 20, 40, 60 and 80 lb. per ac.
Superphosphate: Basal dressing of 1 cwt. per ac. = P_1.
Basal dressing of 2 cwt. per ac. = P_2.
Time of sowing: Early, 24th May = E.
Late, 22nd June = L.
Treatments: All combinations of time of sowing, seed rate, and superphosphate.
Design: 4 randomized blocks of early and late sowing treatment; all combinations of seed rate and superphosphate randomized within each main plot.
Area of main plot = $\frac{8}{50}$th acre; area of sub-plot = $\frac{1}{50}$th acre.

Mean yields of seed in bushels per ac. *Mean of all phosphate* ±0·269.

Time of sowing	Seed rate: lb. per ac. 20	40	60	80	Mean ±0·108	Increase ±0·153
E	9·67	9·02	8·75	7·72	**8·79**	—
L	4·00	6·13	6·39	6·49	**5·75**	*—3·04*
Mean ±0·190	**6·84**	**7·58**	**7·57**	**7·11**	**7·27**	—
Increase ±0·269	—	*0·74*	*—0·01*	*—0·46*	—	—

Significant difference in favour of early sowing: significant interaction of time of sowing and seed rate. Effects of seed rate and P insignificant.

Mean yields of total produce in cwt. per ac. *Mean of all seed rates* ±0·754.

Time of sowing	Phosphate. P_1	P_2	Mean ±0·934	Increase ±1·321
E	44·30	45·82	**45·06**	—
L	27·79	30·01	**28·90**	*—16·16*
Mean ±0·533	**36·05**	**37·91**	**36·98**	—
Increase ±0·754	—	*1·86*	—	—

Mean yields of total produce in cwt. per ac. *Mean of all times of sowing* ±1·066.

Phosphate	Seed rate: lb. per ac. 20	40	60	80	Mean ±0·533	Increase ±0·754
P_1	26·33	37·58	39·91	40·37	**36·05**	—
P_2	27·64	39·09	40·98	43·94	**37·91**	*1·86*
Mean ±0·754	**26·99**	**38·33**	**40·44**	**42·15**	**36·98**	—
Increase ±1·066	—	*11·34*	*2·11*	*1·71*	—	—

Significant increase in favour of early sowing, heavier seed rates, and phosphate.

9. EFFECT OF TOP-DRESSING ON THE YIELD OF NATURAL PASTURE.

Investigation commenced in 1925, on unimproved natural grassland dominated by *Danthonia* spp.

Manurial treatments:

A. Superphosphate 185 lb. (40 lb. P_2O_5) per ac.
B. Superphosphate 185 lb. + nitrate of soda 78 lb. ($12\frac{1}{2}$ lb. N.) per ac.
C. Nil.
D. Ground rock phosphate 103 lb. (40 lb. P_2O_5) per ac.
E. Basic slag 260 lb. (40 lb. P_2O_5) per ac.

} Applied annually.

Plots grazed individually by sheep and estimates of the yields are obtained from 8 protected quadrats, $2\frac{1}{2}$ sq. metres in area, on each plot.

Design: Single replication of the treatments.
Area of plot = 10 sq. chains (10 x 1).

Total yield in cwt. air-dry herbage per ac.

	Treatment					
Year	A	B	C	D	E	Mean
1925	27·74	30·69	21·76	18·57	25·49	**24·85**
1926	43·20	43·57	28·35	27·16	49·15	**38·29**
1927	28·54	27·95	18·00	15·95	24·84	**23·06**
1928	39·63	41·81	24·31	27·89	35·58	**33·84**
1929	33·70	37·45	17·69	25·63	35·31	**29·96**
1930	30·32	39·86	20·67	30·56	43·56	**32·99**
1931	47·50	63·12	41·43	52·60	58·06	**52·54**
1932	75·66	81·11	56·92	70·34	78·25	**72·46**
1933	64·70	63·58	51·43	61·72	57·61	**59·81**
1934	38·00	52·44	20·23	43·66	48·67	**40·60**
1935	72·90	70·90	41·49	58·25	62·72	**61·25**
1936	42·24	48·67	29·54	47·30	41·15	**41·78**
1937	51·69	59·09	36·21	59·48	61·07	**53·51**
1938	54·47	57·62	34·92	60·11	64·06	**54·24**
Mean	**46·45**	**51·28**	**31·64**	**42·80**	**48·97**	**44·23**

Yield of legumes in the pasture. Cwt. air-dry herbage per ac.

Year	Treatment A	B	C	D	E	Mean
1925	20·25	18·35	6·57	5·64	14·35	**13·03**
1926	20·17	16·66	9·49	9·18	19·12	**14·92**
1927	4·29	0·40	1·02	0·44	2·43	**1·71**
1928	23·00	13·78	0·90	3·81	4·28	**9·15**
1929	14·45	8·24	2·18	4·74	13·30	**8·58**
1930	1·71	0·54	0·39	1·57	1·63	**1·15**
1931	6·80	2·79	3·56	5·33	5·18	**4·73**
1932	9·35	7·33	9·94	18·01	12·58	**11·44**
1933	5·40	2·23	4·20	4·24	3·10	**3·83**
1934	1·89	1·17	2·34	1·95	0·06	**1·48**
1935	44·53	27·97	10·14	20·69	18·63	**24·39**
1936	7·84	14·89	8·82	15·08	9·95	**11·32**
1937	19·30	15·15	9·69	14·63	31·34	**18·02**
1938	14·31	4·40	6·83	17·50	15·85	**11·78**
Mean	**13·81**	**9·56**	**5·43**	**8·77**	**10·84**	**9·68**

Stock-carrying capacity. Sheep days of grazing per ac.

Year	Treatment A	B	C	D	E	Mean
1928	900	935	465	640	708	**729**
1929	877	859	509	603	817	**733**
1930	813	1,110	592	667	1,121	**861**
1931	1,271	1,551	902	1,072	1,355	**1,230**
1932	2,421	2,634	1,764	2,215	2,840	**2,375**
1933	2,724	3,211	1,868	2,625	3,175	**2,721**
1934	1,250	1,518	754	1,051	1,370	**1,189**
1935	1,953	2,341	1,431	2,083	2,257	**2,013**
1936	1,237	1,372	691	1,296	1,166	**1,152**
1937	1,618	1,960	1,204	1,863	1,767	**1,682**
1938	2,659	2,768	1,466	2,494	2,591	**2,396**
Mean	**1,611**	**1,842**	**1,059**	**1,509**	**1,742**	**1,553**

10. EFFECT OF DIFFERENT SYSTEMS OF MANAGEMENT ON THE YIELD OF A SEEDED PERMANENT PASTURE.

Pasture mixture: Wimmera rye-grass, perennial rye-grass (New Zealand certified), *Phalaris tuberosa*, and subterranean clover (Dwalganup), sown 3rd June, 1930.

Manurial treatment: Basal dressing of 2 cwt. per ac. superphosphate = P. Sulphate of ammonia, 2 cwt. per ac. = N.

Systems of management:

A. Mown four times per annum, and the pasture removed.
B. Mown as above, but the pasture returned to the plots for grazing by sheep.
C. Grazed by sheep without pre-cutting; sampled for yield from 1932 onwards.
D. Cut as hay at conclusion of seasonal growth.

Design: Sulphate of ammonia applied to strips 400 x 9 links on the ABBA system in quadruplicate.

Area subdivided into 4 blocks, to each of which is applied one system of management.

Yield of herbage in cwt. per ac.

	System of Management.							
	A		B		C		D	
Year	P	PN	P	PN	P	PN	P	PN
1930	40·95	44·20	28·09	32·02	*	*	30·44	37·32
1931	20·90	31·64	32·41	42·64	*	*	24·96	45·58
1932	38·13	34·89	41·80	45·66	50·55	60·34	63·74	62·36
1933	38·36	32·39	25·13	21·88	28·57	25·65	65·55	61·81
1934	51·86	49·03	58·93	62·32	88·33	76·52	48·44	45·80
1935	57·97	50·88	51·15	49·35	63·71	67·03	67·39	62·92
1936	47·41	43·79	42·24	43·10	58·68	62·37	39·96	38·39
1937	46·53	45·62	48·48	52·04	55·52	57·70	55·63	54·14
1938	41·62	35·85	37·80	37·00	62·69	68·35	59·81	57·23
Mean	**42·64**	**40·92**	**40·67**	**42·89**	**58·29**	**59·71**	**50·66**	**51·73**

* Records not taken.

Total yields of the principal botanical constituents in cwt. per ac. 1933–38.

System of management.	*Lolium*		*Phalaris*		*Trifolium*		Total Sown Species.	
	P	PN	P	PN	P	PN	P	PN
A	36·47	60·13	121·16	108·61	111·27	66·06	268·90	234·80
B	70·74	93·78	142·33	124·62	28·46	8·25	241·53	226·65
C	47·70	64·99	241·94	232·29	24·79	6·76	314·43	304·04
D	16·00	24·43	268·55	236·33	2·35	0·68	286·90	261·44

11. EFFECT OF SUPERPHOSPHATE AND SURFACE CULTIVATION ON THE YIELD AND BOTANICAL COMPOSITION OF A SEEDED PASTURE.

Pasture mixture:

Phalaris tuberosa, 5 lb. per ac.
Wimmera rye-grass, 1 lb. per ac.
Subterranean clover (Dwalganup), 5 lb. per ac.
} Sown 15th May, 1936.

Superphosphate:

None = P_0.
1 cwt. per. ac. per annum = P_1.
2 cwt. per ac. per annum = P_2.
3 cwt. per ac. per annum = P_3.

Cultivation: Surface cultivation annually each autumn and no surface cultivation.

Design: Phosphate treatments arranged in a 4 x 4 Latin square.

Area of main plot = $\frac{1}{12 \cdot 5}$ acre. Half of each main plot surface cultivated.

Plots cut and grazed 4 times annually at 6-weekly intervals.

Yield of oven-dry matter in cwt. per ac.

1937	P_0	P_1	P_2	P_3	Mean ±0·96
No cultivation	23·28	29·79	31·05	32·47	**29·15**
Cultivated	26·55	25·56	30·70	33·34	**29·04**
Mean ±1·16	**24·91**	**27·68**	**30·88**	**32·91**	**29·10**
1938					Mean ±1·00
No cultivation	29·02	43·27	39·88	38·98	**37·79**
Cultivated (1937 only)	31·41	39·59	42·25	44·27	**39·38**
Mean ±1·20	**30·21**	**41·43**	**41·07**	**41·63**	**38·58**

Botanical composition expressed as percentage.

1937.	Wimmera rye-grass.	*Phalaris.*	Sub. Clover.	Misc.	Total.
P_0	14·7	53·0	31·5	0·8	100·0
P_1	17·1	43·0	38·6	1·3	100·0
P_2	14·8	43·8	40·9	0·5	100·0
P_3	17·1	46·5	35·8	0·6	100·0
1938					
P_0	10·1	47·6	36·6	5·7	100·0
P_1	17·2	48·0	29·4	5·4	100·0
P_2	18·3	50·6	26·8	4·3	100·0
P_3	18·8	51·1	25·3	4·8	100·0

12. EFFECT OF DIFFERENTIAL GRAZING MANAGEMENT ON A SEEDED PASTURE.

Pasture mixture:

Phalaris tuberosa, 5 lb. per ac.
Wimmera rye-grass, 1 lb. per ac.
Subterranean clover (Dwalganup), 5 lb. per ac.
} Sown 15th May, 1936.

Manurial treatment: Superphosphate, 2 cwt. per ac. per annum.

Intensities of grazing: 2, 4, and 6 sheep per ac. per annum.

Grazing cycles: 3, 6, and 9 weeks.

Hay treatment: Hay and no hay.

Treatments: All combinations of intensity of grazing, grazing cycle, and hay treatment.

Design: 18 treatments arranged in 3 randomized blocks.

Area of plot = 1/7th acre. Each plot separately fenced. Each plot individually grazed by Merino wethers for 6 days in each cycle.

Mean annual yield of oven-dry herbage in cwt. per ac. 1937–38 (no hay plots only).

Intensity of grazing Sheep per ac. per annum.	Grazing cycle (weeks). 3	6	9	Mean.
2	32·15	42·28	36·12	**36·85**
4	29·27	33·82	38·94	**34·01**
6	24·97	36·69	34·81	**32·16**
Mean	**28·80**	**37·60**	**36·62**	**34·34**

Mean hay yields in cwt. per ac. 1937–38.

Intensity of grazing Sheep per ac. per annum.	Grazing cycle (weeks). 3	6	9	Mean.
2	36·45	35·94	40·67	**37·69**
4	38·25	28·68	22·57	**26·50**
6	26·91	30·39	25·72	**27·67**
Mean	**33·87**	**31·67**	**29·65**	**31·73**

Mean live-weight gains in kilograms per sheep per 6-day period of grazing, 1937–38.

Intensity of grazing Sheep per ac. per annum.	Grazing cycle (weeks). 3	6	9	Mean.
2	1·5	1·9	2·5	**2·0**
4	1·7	2·0	2·3	**2·0**
6	1·1	1·5	1·6	**1·4**
Mean	**1·4**	**1·8**	**2·1**	**1·7**

Percentage botanical composition (69 weeks after commencement of experiment).

	Intensity of grazing sheep per ac. per annum.	Wimmera rye-grass.	*Phalaris.*	Sub. Clover.	Misc.	Total.
No hay	2	1·4	66·1	29·2	3·3	100·0
	4	3·1	53·3	36·4	7·2	100·0
	6	2·7	51·3	37·0	9·0	100·0
Hay	2	1·1	58·8	36·4	3·7	100·0
	4	1·4	46·0	43·3	9·3	100·0
	6	1·6	51·6	39·3	7·5	100·0
	Grazing cycle (weeks)					
No hay	3	2·0	57·7	34·7	5·6	100·0
	6	2·3	55·9	33·6	8·2	100·0
	9	2·6	58·9	33·5	5·0	100·0
Hay	3	0·8	48·7	46·2	4·3	100·0
	6	1·5	51·8	39·4	7·3	100·0
	9	1·6	56·5	33·6	8·3	100·0

13. COMPARISON OF THE GRAZING VALUE OF TOP-DRESSED NATURAL AND SEEDED PASTURES AT (1) WAITE INSTITUTE, (2) KYBYBOLITE.

Four areas each of natural pasture, Wimmera rye-grass + subterranean clover, and of *Phalaris tuberosa* + subterranean clover aggregating 10·5 acres of each type of pasture at the Waite Institute, and 17·00, 17·93, and 17·75 acres respectively at Kybybolite.

Manurial treatment: 2 cwt. per ac. superphosphate applied annually in the autumn.

System of management: Grazed rotationally by sheep. Three uniform flocks, one of 16 wethers and two each of 32, were allocated to the natural pasture and sown pastures respectively at the Waite Institute: 4 sheep of each flock were taken on 21/7/36 to comprise a group of 12 sheep grazing on each type of pasture in turn. At Kybybolite three flocks each of 40 comeback ewe weaners were selected for the three pasture types.

Live weights of sheep taken fortnightly at the Waite Institute, monthly at Kybybolite: yields of pasture from enclosed quadrat areas: hay cut 1936 and 1937 at Waite Institute: wool and lambing data.

Commencement of grazing: Waite Institute, 1/7/35; Kybybolite, 14/4/35.

Live weight increase per ac. in lb. of each flock.

Flock.	Waite Institute (1/7/35–5/7/38).	Kybybolite (14/4/35–6/12/38).
Natural pasture	105·4	139·9
Wimmera rye-grass + sub. clover	234·0	170·2
Phalaris + sub. clover	224·7	166·8
Rotational (21/7/36–5/7/38)	100·8	—

Mean weight and value of wool per sheep.

	Waite Institute.						Kybybolite.								
	1936.			1937.			1936.			1937.			1938.		
Flock.	lb.	oz.	value.	lb.	oz.	value.	lb.	oz.	value.	lb.	oz.	value.	lb.	oz.	value.
			s. d.			s. d.			s. d.			s. d.			s. d.
Natural pasture	12	12·2	16/9	14	10·6	22/0	6	8·6	9/7	11	7·4	17/6	10	4·6	10/10
Wimmera rye-grass + sub. clover	12	15·5	17/2	14	5·6	22/2	6	13·8	10/2	12	12·3	19/7½	10	7·5	10/9½
Phalaris + sub. clover	12	7·0	16/8	13	4·3	20·8	7	6·4	11/1	12	8·4	19/11	10	13·4	11/1½
Rotational	12	4·8	16/5	13	1·6	20/2									

Mean yields of oven-dry herbage in cwt. per ac.

	Waite Institute.			Kybybolite.		
Flock.	1935.	1936.	1937.	1935.	1936.	1937.
Natural pasture	42·01	21·64	44·26	58·24	52·13	48·41
Wimmera rye-grass + sub. clover	58·87	35·01	51·61	62·94	71·89	56·58
Phalaris + sub. clover	47·18	27·11	42·56	62·26	59·22	57·30

Yield of air-dry hay (cut from 5·25 ac.).

	Waite Institute.			
	1936.		1937.	
Flock.	cwt.	lb.	cwt.	lb.
Natural pasture	34	99	171	96
Wimmera rye-grass + sub. clover	65	31	227	72
Phalaris + sub. clover	33	77	188	89

Percentage lambing of ewes of each flock.

	Kybybolite.			
Flock.	1936.	1937.	1938.	Mean 1936–8.
Natural pasture	65·8	86·5	100·0	84·1
Wimmera rye-grass + sub. clover	85·0	100·0	112·8	99·3
Phalaris + sub. clover	82·5	85·0	117·9	95·1

14. YIELD TRIAL OF NEW CROSSBRED WHEATS, 1936.

Variety: Nabawa used as standard.

Seed rate per ac.: A, 78 lb.; B, 90 lb.

Manurial treatment: 2 cwt. per ac. superphosphate.

Design: A. Four randomized blocks of 10 strains sown 8th June.

B. Four randomized blocks of 10 strains sown 8th July.

Rainfall (seeding to harvest): A, 12·85 inches; B, 10·83 inches.

Yield results:

A.

Strain number.	Strain or variety.	Mean yield bush. per ac.	Per cent. yield of Nabawa.	Days to heading.
33–101	Sepoy Selection	47·16	121	126
35–66	Federation x Minister	46·94	120	127
35–82	Nabawa x Hard Federation	46·94	120	126
35–38	Gluyas x Minister	45·83	117	121
35–49	Nabawa x Hard Federation	43·71	112	124
35–34	Ford x Hard Federation	40·31	103	121
35–61	Sepoy x Federation	40·03	103	129
35–63	Nabawa x Hard Federation	39·58	101	127
—	Nabawa	39·03	100	121
35–67	Nabawa x Hard Federation	35·68	91	129

Significant difference between mean yields 3·03 bush. per ac.

B.

35–2	Nabawa x Hard Federation	50·86	128	90
35–16	Hard Federation x Gluyas	45·88	116	96
35–17	Hard Federation x Gluyas	45·83	116	96
35–22	Sepoy Selection R.R.	45·46	115	98
35–37	Federation x Gluyas	43·47	110	98
35–43	Hard Federation x Gluyas	43·21	109	98
35–47	Hard Federation x Gluyas	41·74	105	99
35–53	Gluyas x Minister	41·11	104	97
35–32	Gluyas Natural Hybrid	40·95	103	97
—	Nabawa	39·65	100	98

Significant difference between mean yields 2·99 bush. per ac.

15. YIELD TRIAL OF NEW CROSSBRED WHEATS, 1937.

Variety: Ranee 4H used as standard.
Seed rate per ac.: A, 78 lb.; B, 90 lb.
Manurial treatment: 1 cwt. per ac. superphosphate.
Design: A. Four randomized blocks of 10 strains sown 10th June.
B. Four randomized blocks of 10 strains sown 29th June.
Rainfall (seeding to harvest): A, 15·19 inches; B, 13·33 inches.

Yield results:

A.

Strain number.	Strain or variety.	Mean yield bush. per ac.	Per cent. yield of Ranee 4H.	Days to heading.
36–61	Nabawa x Hard Federation	38·7	103	122
35–66	Federation x Minister	37·8	101	125
36–72	Ford x Hard Federation	37·7	101	120
—	Ranee 4H	37·4	100	122
36–48	Gluyas x Hope	37·3	99	122
36–66	Nabawa x Hard Federation	37·1	99	125
36–44	Ford x Hard Federation	35·6	95	122
35–82	Nabawa x Hard Federation	34·3	92	122
33–101	Sepoy Selection	33·2	89	124
36–46	Ford x Hard Federation	33·1	88	119

Significant difference between mean yields 3·02 bush. per ac.

B.

36–4	Hard Federation x Gluyas	43·8	109	98
36–6	Nabawa x Hard Federation	42·7	106	101
—	Ranee 4H	40·3	100	109
36–17	Gluyas Natural Hybrid	39·8	99	106
36–26	Nabawa x Hard Federation	39·3	98	109
36–18	Hard Federation x Gluyas	38·9	97	106
36–41	Ford x Hard Federation	37·8	94	105
36–9	Ford x Hard Federation	37·4	93	103
36–84	Baringa	37·1	92	105
36–19	Hard Federation x Gluyas	36·8	91	112

Significant difference between mean yields 2·66 bush. per ac.

16. YIELD TRIAL OF NEW CROSSBRED WHEATS, 1938.

Variety: Ranee 4H used as standard.
Seed rate per ac.: A, 78 lb.; B, 90 lb.
Manurial treatment: 1½ cwt. per ac. superphosphate.
Design: A. Four randomized blocks of 10 strains sown 8th June.
B. Four randomized blocks of 10 strains sown 29th June.
Rainfall (seeding to harvest): A, 10·40 inches; B, 8·78 inches.

Yield results:

A.

Strain number.	Strain or variety.	Mean yield bush. per ac.	Per cent. yield of Ranee 4H.	Days to heading.
33–101	Seewari	42·12	111	126
37–457	Sepoy Selection	40·84	107	121
37–454	Sepoy Selection	40·38	106	121
37–413	Ford x Hard Federation	39·44	103	118
37–442	Hard Federation x Gluyas	38·36	101	119
—	Ranee 4H	38·05	100	121
37–464	Ford x Hard Federation	37·33	98	121
37–462	Nabawa x Hard Federation	37·12	97	122
37–453	[Gluyas(w) x Hope]^2 x Nabawa	36·87	97	134
36–72	Ford x Hard Federation	34·70	91	121

Significant difference between mean yields 3·66 bush. per ac.

B.

37–403	Nabawa x Hard Federation	40·37	121	99
36–4	Hard Federation x Gluyas	40·11	120	97
36–6	Nabawa x Hard Federation	38·64	116	100
36–17	Gluyas Natural Hybrid	38·27	114	106
37–443	Nabawa x Hard Federation	37·06	111	107
37–433	Ford x Hard Federation	36·85	110	107
37–417	Hard Federation x Gluyas	36·70	110	106
36–18	Waria	36·28	109	106
37–446	Hard Federation x Gluyas	35·70	107	107
—	Ranee 4H	33·39	100	107

Significant difference between mean yields 1·91 bush. per ac.